Agricultural origins on the Anatolian plateau

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Abstract

This paper explores the explanations for, and consequences of, the early appearance of food production outside the Fertile Crescent of Southwest Asia, where originated in the 10th/9th millennia cal BC. We present evidence that cultivation appeared in Central Anatolia through adoption by indigenous foragers in the mid 9th millennium cal BC, but also demonstrate that uptake was not uniform, and that some communities chose to actively disregard cultivation. Adoption of cultivation was accompanied by experimentation with sheep/goat herding in a system of low-level food production that was integrated into foraging practices rather than used to replace them. Furthermore, rather than being a short-lived transitional state, low-level food production formed part of a subsistence strategy that lasted for several centuries, though its adoption had significant long-term social consequences for the adopting community at Boncuklu. Material continuities suggest that Boncuklu's community was ancestral to that seen at the much larger settlement of Çatalhöyük East from 7100 cal BC, by which time a modest involvement with food production had been transformed into a major commitment to mixed farming, allowing the sustenance of a very large sedentary community. This evidence from Central Anatolia illustrates that polarized positions explaining the early spread of farming, opposing indigenous adoption to farmer colonization, are unsuited to understanding local sequences of subsistence and related social change. We go beyond identifying the mechanisms for the spread of farming by investigating the shorter and longer-term implications of rejecting or adopting farming practices.

Key words:

Neolithic; spread of farming; early herding; Anatolia; low-level food production.

Significance statement

We demonstrate that the initial spread of farming outside of the area of its first appearance in the Fertile Crescent of SW Asia, into central Anatolia, involved adoption of cultivars by indigenous foragers and contemporary experimentation in animal herding of local species. This represents a rare clear-cut instance of forager adoption and sustained low-level food production. We have also demonstrated that farming uptake was not uniform with some forager communities rejecting it, despite proximity to early farming communities. We also show that adoption of small-scale cultivation could still have significant social consequences for the communities concerned. The evidence suggests forager adoption of cultivation and initiation of herding was not necessarily motivated by simple economic concerns of increasing levels of food production and security.

Introduction

From its emergence in the 10th and 9th millennia cal BC in the Fertile Crescent of Southwest Asia (1, 2), agriculture increasingly dominated subsistence practices across western Eurasia and supplanted foraging as the primary means of food acquisition for many human communities. How and why the Southwest Asian form of agriculture expanded beyond its area of origin has been the subject of debate for decades. As with other instances of the spread of farming two explanations traditionally dominated discussions, namely that cultivation and herding was spread by colonising agriculturalists – the demic diffusion model – (3,4) or that these practices were adopted by foragers after contact with agriculturalists (5). Moving beyond the polarised positions offered by these explanations, recent critiques have suggested that a more fluid and variable pattern of change may have occurred during the adoption of food production (6). In practice these critiques have not generally broken down the widespread classic forager–agriculturalist analytical dichotomies (7) attested in much of the literature on the spread of farming, probably because they have not been evidenced through the compilation of detailed local scale archaeological and palaeoenvironmental histories.

A key region for testing our understanding of the economic, social and cultural history of food production, as it spread, is the high altitude Central Anatolian plateau, which has some of the earliest evidence for the development of sedentary and agricultural societies beyond the Fertile Crescent. Often attributed to demic diffusion, an understanding of how agriculture spread into Central Anatolia, as in many regions, has been obscured by a lack of detailed local-scale archaeological and palaeoenvironmental histories in which the relationships between social and economic change can be closely investigated through time. This paper presents an analysis of a wide range of evidence, from the sites of Pınarbaşı and Boncuklu for the first appearance of agriculture in the second half of the 9th millennium cal BC in the Konya Plain of Central Anatolia. As a result of the work of our projects reported herein the settlement record of Central Anatolia now stretches from the Epipalaeolithic into the early Holocene and is thus contemporary with the Levantine Natufian and earlier Aceramic Neolithic (PPNA, Early and Middle PPNB). Recent work has shown there is evidence for a significant degree of cultivation and caprine herding before 8,000 cal BC at Aşıklı Höyük in Cappadocia (8, 9), and large scale mixed farming, that is the integrated cultivation and herding of fully domestic cereals, legumes and caprines by at least 7100 cal BC on the Konya Plain at Çatalhöyük East (10). The evidence presented here, covering the early part of the early Holocene from c. 9800-7800 cal BC, provides new insights into the context, origins and outcomes of the appearance of agriculture in the region, questioning the dominant view that the spread of cultivation in areas beyond the Fertile Crescent resulted from colonisation by migrant farming communities. As well as providing an archaeological example of the spread of agriculture in prehistory through social interactions, the paper also aims to explore the social and cultural consequences of the decision to adopt or reject farming for Anatolia's early Holocene communities.

Background

As in other geographical areas, interpretations of how agriculture – here defined broadly as the cultivation of plants and herding of animals – spread onto the Anatolian plateau have been dominated by two polarised positions. One posits that cultivation and/or herding spread into the region with farmers, possibly as part of a Neolithic Demographic Transition, in which growing population in successful farming regions pushed some people to colonize new areas and regions (3). This claim has been most clearly expressed for Central Anatolia by research that used the similarity of Central Anatolian Neolithic crop and weed seed packages to those from northern Syria to suggest the introduction of cultivation by colonizing farmers from that region (11). Whilst these similarities, as with evidence for obsidian distributions, point to meaningful interactions between settlements across these regions, they do not themselves identify the mechanism by which the crops spread. Rather, they demonstrate a possible point of origin from which they might well have diffused by other mechanisms, including exchange, well evidenced at these periods.

Opposing approaches propose that foragers were responsible for the spread of agriculture by adopting it from farmers with whom they were in contact. In Central Anatolia material culture continuity with the Epipalaeolithic combined with borrowed features from the Pre-Pottery Neolithic B (PPNB — c 8500-7000 cal BC) of the Levant have been used to identify local indigenous contributions to the development of animal husbandry at Aşıklı (8). Adoptionist models have been best developed in Europe (5, 6, 12) with the most detailed seeing a long 'availability' phase of several centuries at the forager-farmer 'frontier zone', giving way to a competitive and, therefore, unstable 'substitution' phase, where crops and animals were incorporated into food acquisition practices on a small-scale basis, and then a 'consolidation' phase of larger scale agricultural production (6, 12). Rapid uptake of agriculture during the substitution phase – in effect an unstable transition point – is a key element of this model, separating distinct phases of foraging and farming that are considered economically and socially incompatible (12).

In recent years these polarised interpretations have been modified to admit more overlap; colonization proponents suggesting the possibility of small-scale forager adoption and assimilation within the context of broader colonizing processes, and adoption models including options for the small-scale movement of some farmers as part of the transfer processes of farming practice (5). Despite this narrowing of the gap between extremes, most accounts still envisage broad processes at either end of a possible spectrum, with significant regions representing one broad process or another (3-5,10,13).

Such dichotomous thinking is largely a product of fundamentally different *a priori* understanding of foragers and small-scale early farming communities. At the heart of colonizer models is an understanding that foragers would not find cultivation or herding attractive prospects (3, 4), with limited time invested in subsistence pursuits, and practices such as residential mobility and generalized reciprocity militating against the adoption of cultivation (14, 15). Furthermore, transmission of knowledge about agricultural species, practices and management might have faced social barriers, relying on long-term observation and/or close interpersonal communication that would have been easier within rather than between communities (4). However, recent ethnographic work has raised significant

challenges to these assumptions, suggesting less uniformity and more flexibility in many forager practices, including time invested in subsistence activities, generalized reciprocity, social practice and degrees of mobility (16-18). Dichotomous models ultimately present a narrow range of possibilities for the spread of agriculture in prehistory based on a shallow historical understanding of foragers and farmers, often drawn from recent colonial experiences. It is very likely that the social practices, behaviours, identities and world-views of foragers and farmers of the late Pleistocene and early Holocene were quite different from societies encountered over the past 500 years (1, 19, 20).

The sites, their landscapes and chronology

We address the issue of agricultural transition in Central Anatolia using new archaeological evidence from the excavation of two settlements in Turkey's Konya plain. Pınarbaşı (21) is located on the eastern edge of the southwest Konya basin (Fig. 1), with the 10th-9th millennium cal BC settlement mound located a few tens of metres away from the Epipalaeolithic and Late Neolithic rockshelter (22). Boncuklu (23) is located 31 km to the northwest, in the centre of the same basin, 9.5 km northeast of Çatalhöyük East (Fig. 1). Both settlements are c. 1 ha in area (SI Appendix, Figs. S1 and S4) and consist of sub-oval domestic buildings, at Pınarbaşı with wattle and daub superstructures (21), and at Boncuklu with mudbrick superstructures (23), in both cases interspersed with open spaces. In contrast the later site of Çatalhöyük East is a much larger mound of 13 ha in area with densely packed rectangular mudbrick houses (10, 24, 25).

Accelerator mass spectrometry (AMS) radiocarbon dating of a total of 16 short life samples from Pınarbaşı, including those from *in situ* contexts such as burials and floors, combined with Bayesian analysis of site sequences provide a site chronology (See SI Appendix, SI Text 1). This analysis indicates that occupation in Area D, one of the two trenches excavated into the early Holocene settlement mound, started at, or just after, the Pleistocene/Holocene transition, around 9800–9400 cal BC (SI Appendix, Fig. S1 and S2 and Table S2) with earlier phases of occupation in Area A (SI Appendix, Fig. S1) dated from around 9000 cal BC (SI Appendix, Table S1), although this does not date the beginning of the sequence in Area A. In both excavation areas occupation appears to have continued through the 9th millennium cal BC ending between 8200 and 7800 cal BC (SI Appendix, Figs. S2 and S3). Bayesian analysis of the stratigraphic sequence (SI Appendix, SI Text 1, Fig. S3, and Table S1) indicates that the site occupation ended around 8,000 cal BC, though a date from context ADK, in a long lasting final phase of deposition, suggests occupation may well have continued into the early 8th millennium (SI Appendix, Fig. S3). Thus the sequence chronologically spans much of the Levantine Pre-Pottery Neolithic (PPN) A and Early to Middle PPNB, during which agriculture first emerges in the Fertile Crescent.

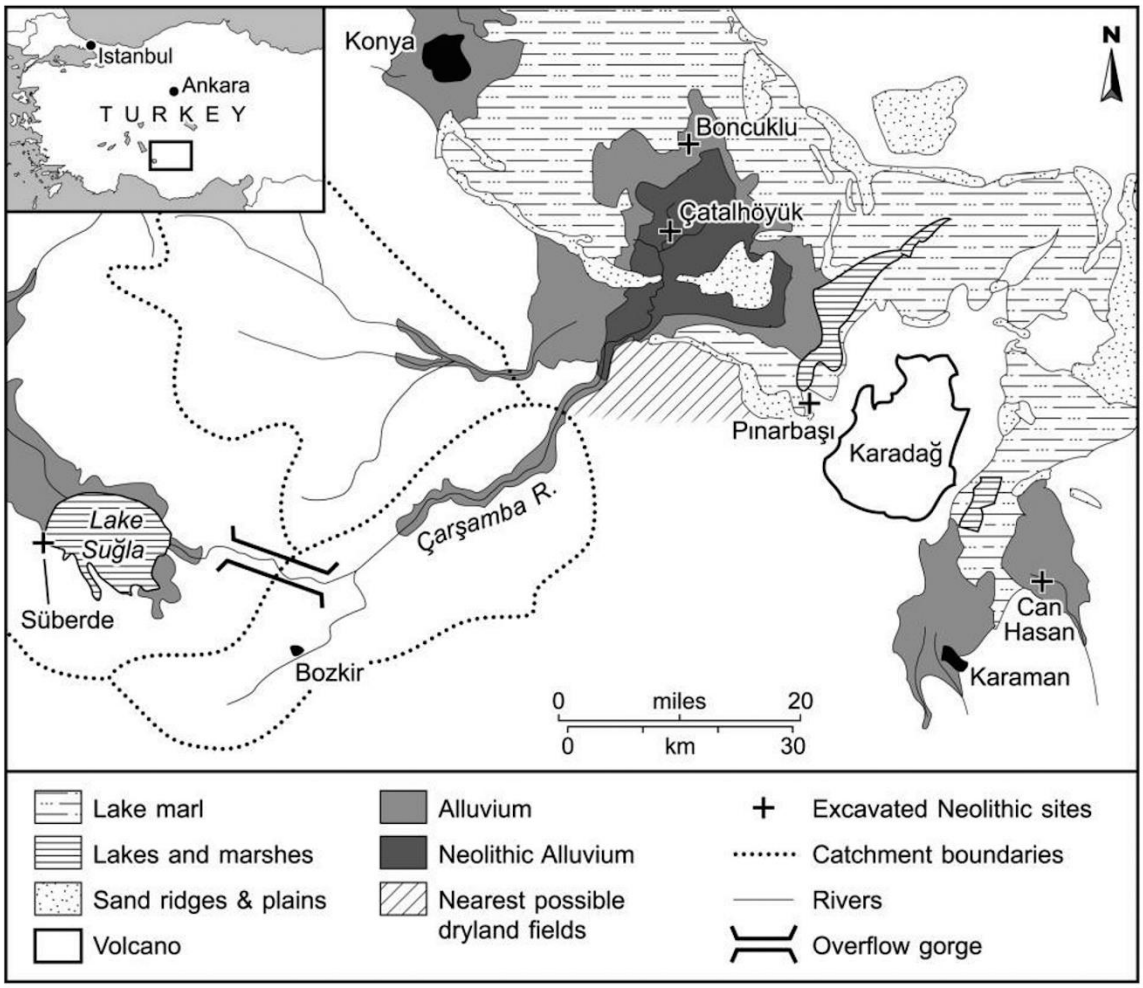

Figure 1 Map of central Anatolia showing the principal sites mentioned in the text

Bayesian analysis of the Boncuklu sequence of C14 dates, derived from 9 short-life seed and nut remains and *in situ* human burials from Area H (SI Appendix, Figs. S4 and S5), suggests an early settlement phase of c. 8300–8100 cal BC and a later phase of c. 8100–7800 cal BC (SI Appendix, SI Text 1, Fig. S5, and Table S3) from those preserved occupation deposits which have been the focus of excavation to date. Chipped stone points in the latest levels, similar to Musular (c. 7600–7000 cal BC) (26), Canhasan III (c. 7,400–7,100 cal BC) and early Çatalhöyük c. 7100–7000 cal BC (27), suggest occupation after 7600 cal BC, although we have not yet located reliable *in situ* dating samples from those latest contexts.

These results confirm that the early phases at Pınarbaşı form the earliest dated Holocene settlement in central Anatolia, predating the settlement at Boncuklu by c. 1200 years. The two sites were contemporary settlements for at least 300-500 years, and Boncuklu continued to be occupied for a few centuries after Pınarbaşı. Both sites are at least partially contemporary with levels 4 and 3 at Aşıklı in Cappadocia and Pınarbaşı is probably earlier than and contemporary with Aşıklı level 5 (8, 9).

Abundant off-site geomorphological evidence (28) and on-site archaeological data, point to the presence of a wetland steppe mosaic on the plain in the early Holocene, including

streams, lakes and wetlands, some located close to both sites. Boncuklu's anthracological assemblage records a wide diversity of taxa, despite the overall low density of wood charcoal macroremains, dominated by wetland/riparian plants such as willow/poplar, that comprising 64–71% of the sample re. 29, table 1. Seed data (SI Appendix, Text 2, Tables S4 and S5) also show a high abundance of wetland species, including indicators of open water and marsh/riparian habitats, as do the phytoliths, which are dominated by reed forms (SI Appendix, SI Text 3, and Fig. S9). Combined with faunal evidence for large mammals, whose habitats include marshy conditions (See SI Appendix, SI Text 4), fish and waterfowl, these data indicate the presence of extensive wetland areas around Boncuklu and overwhelmingly demonstrate the significance of wetland exploitation for the community. Regular, but lower frequency, exploitation of the semi-arid woodland of almond, terebinth and oak, located on the hills and their fringes on the edge of the plain is indicated by anthracological (29), seed and faunal data (See SI Appendix, SI Text 1, 2 and 3).

While wetland plant exploitation is evidenced at Pınarbaşı the plant record is dominated by almond and other species indicative of semi-arid steppe woodland (30, 31), indicating a greater exploitation of the hill zone for fuel and structural wood than at Boncuklu. The Pınarbaşı faunal assemblage (See SI Appendix, SI Text 4), shows the exploitation of animals from hill, wetland and steppe environments. Several Pınarbaşı data sets, therefore, suggest a relatively balanced exploitation of plain and hill resources, reflecting the ecotonal location of Pınarbaşı in contrast to that of Boncuklu, which is more wetland focused.

Plant exploitation

Archaeobotanical sampling at Pınarbaşı (30) and Boncuklu (SI Appendix, SI Text 2, and Table S4) demonstrates that the two settlements had differing plant-based subsistence practices (Tables 1 and 2). Both saw the collection of almonds, terebinth nuts and hackberry fruits, with a focus on almond exploitation at Pınarbaşı (30), perhaps reflecting the proximity of the site to almond-rich woodland on the Karadağ (29, 31). Nuts form a common element of the assemblage at Boncuklu alongside clubrush (*Bolboschoenous glaucus*) tubers (Tables 1 and 2 and SI Appendix, Table S4 and S5), perhaps indicating a local adaptation to an abundance of these resources, also found at Çatalhöyük East. There is currently no clear evidence for the collection and processing of wild plant seeds at Pınarbaşı, where the main species present are unlikely foods (30). Boncuklu's seed assemblage is extremely rich and dominated by a range of wetland plant seeds (SI Appendix, SI Text 2, and Tables S4 and S5), several of which (*Bolboschoenous glaucus*, docks and knotweeds) have been identified as food species in contemporary sites in other regions (32). While use of these seeds for food is possible, other explanations are plausible including the introduction of seeds to the site as part of the reed fuel load evidenced in macrofossil (SI Appendix, SI Text 2, Fig. S6, and Table S4) and microfossil assemblages (SI Appendix, SI Text 3, and Fig. S9). Several wetland plant species also have a high, significant correlation with cultivars, suggesting that some may have arrived as cultivation weeds (SI Appendix, SI Text 2 and Table S5).

A fundamental difference between the sites is in the evidence for cultivation: 10th–9th millennium Pınarbaşı shows no evidence for the cultivation or gathering of cereals and

legumes (Tables 1 and 2): the few crop remains in $10^{th}/9^{th}$ millennium deposits were intrusive, the typical range of weeds associated with cultivation for this period were lacking, and abundant phytoliths showed no evidence for the presence of wheat and barley (30). Boncuklu shows sparse, yet well-dated and compelling evidence for the presence of cereals, legumes and their weeds in the seed (Tables 1 and 2 and SI Appendix, SI Text 2 and Table S4) and phytolith assemblages (SI Appendix, SI Text 3 and Fig. S9). At Boncuklu probable crop seeds and chaff form 1.1% of the archaeobotanical assemblage (Tables 1 and 2 and SI Appendix, Table S4), being present in c. 50% of the analysed contexts. All of the crop remains were poorly preserved but the grains and chaff of emmer and einkorn wheat were identified plus two 'New Type' wheat spikelet forks, among the earliest known in southwest Asia (Tables 1 and 2). Wild einkorn and probable wild type emmer grains were present, as well as several large emmer grains (SI Appendix, SI Text 2, Fig. S7b) typical of cultivated types (for definition see SI Appendix, Text 2). Most chaff was too damaged for unambiguous distinction of wild/domestic status, though two non-basal emmer spikelet forks preserved undamaged domestic type rachis scars present (SI Appendix, SI Text 2). Direct AMS dating has confirmed the age of emmer and einkorn chaff, demonstrating that they are not intrusive from later uses of the site. Phytoliths, trapped in a reed leaf mat on a building floor, confirmed the *in situ* presence of wheat. Cultivated barley and its wild relatives are lacking, with barley phytoliths probably from the small seeded weedy barley species that are found in the macrofossil assemblages (SI Appendix, SI Texts 2 and 3). AMS dates confirmed that the naked wheat and hulled barley remains reported earlier (23) were contaminants from recent occupation. Also present is lentil and pea (Tables 1 and 2), the latter including a small number with rough (wild-type) and smooth (domestic-type) testas preserved among a range of other large-seeded legumes.

Table 1. Summary of plant macrofossil data (NISP sum and % frequency of key macrofossil classes from Boncuklu and trenches at Pınarbaşı)

Key plant classes	Site							
	Boncuklu		Pınarbaşı D		Pınarbaşı Late A		Pınarbaşı Early A	
Contexts analyzed	45		8		19		13	
Sample volume	3,184		473		1,499		675	
NISP, sum (% frequency)								
Total	36,060	(100.00%)	1,071	(100.00%)	3,408	(100.00%)	2,381	(100.00%)
Cereal grain	38	(0.11%)	0	(0.00%)	0	(0.00%)	0	(0.00%)
Cereal chaff	31	(0.09%)	0	(0.00%)	0	(0.00%)	0	(0.00%)
Pulses	307	(0.85%)	0	(0.00%)	0	(0.00%)	0	(0.00%)
Nutshell (charred)	257	(0.71%)	328	(30.63%)	1,329	(39.00%)	281	(11.80%)
Nutshell (not charred)	346	(0.96%)	22	(2.05%)	70	(2.05%)	139	(5.84%)
Wild seeds (charred)	29,390	(81.50%)	109	(10.18%)	747	(21.92%)	265	(11.13%)
Wild seeds (not charred)	5,691	(15.78%)	612	(57.14%)	1,262	(37.03%)	1,696	(71.23%)

For full data see *SI Appendix*, Table S4.

The presence of wheat chaff macrofossils and phytoliths, plus the seeds of several agricultural weeds (SI Appendix, SI Text 2, Tables S4 and S5) found commonly in other early farming sites (24, 34) suggests that crops were cultivated and processed at Boncuklu. Several probable weeds have strong correlation coefficient values with legume and cereal remains (SI Appendix, SI Text 2, and Table S5), among them wet loving species whose presence, with the dominance of multi-cell cereal phytoliths (SI Appendix, SI Text 3),

suggest that some crops were grown in relatively well-watered conditions, such as those that would have been located close to Boncuklu.

In overall composition the economic seed assemblage is very similar to those from contemporary sites in southeast Anatolia and the eastern Fertile Crescent, with a small amount of cereals and legumes, with legumes most abundant, used alongside a range of possible foraged wild foods (2, 32, 34, 35). Cropping is far less visible at Boncuklu (1.1% of the assemblage and 50% ubiquity) than in the partially contemporary occupation at Aşıklı Level 2 where crops form 70% of the assemblage and were present in c.80% of samples (36, 37). A contrast can also be drawn at Çatalhöyük East, whose early assemblages (Mellaart Pre-Level XII) are similar to those from Boncuklu, having many wetland plant seeds and little wood, where crops form c.35% of the assemblage and are present in 100% of samples (25, 38). The low frequency of crops in an otherwise abundant plant assemblage, suggests that cultivated plants were used and processed in modest quantities at Boncuklu. This is also supported by material culture evidence. Rare bone sickle hafts and two flint sickle blades hint at some plant reaping at Boncuklu, but obsidian microwear studies have yet to identify obsidian sickle blades and extensive archaeobotanical evidence for the use of reeds and sedges suggest a potential alternative purpose for those few sickle tools we have identified. In addition, there are no built *in situ* storage bins or likely storage pits in Boncuklu's buildings, such as at later Çatalhöyük, and possible storage bins/pits are also uncommon outside buildings, suggesting plant food storage was modest in scale, perhaps mostly in baskets or bags. While grinding stones are present, the site lacks the larger grinders, mortars and pestles seen at Pınarbaşı and could also have performed other functions such as grinding ochre and organic tools.

Table 2. Standardized counts, ubiquity, and % frequency of the probable crops at Boncuklu

Taxon	English name	Component	Sum	Ubiquity	% Frequency
Cereals					
Triticum dicoccum and/or *T. dicoccoides*	Wild emmer wheat	Grain MNI	6	3	6.7
Triticum monococcum and/or *T. boeoticum*	Wild einkorn wheat	Grain MNI	9	6	13.3
Triticum monococcum or *T. dicoccum*	Wild einkorn or wild emmer	Grain MNI	2	1	2.2
Triticum spp.	Wheat	Grain MNI	3	3	6.7
Cereal indeterminate		Grain MNI	6	6	13.3
Triticum dicoccum and/or *T. dicoccoides*	Wild emmer wheat	Glume base	13	4	8.9
Triticum monococcum and/or *T. boeoticum*	Wild einkorn wheat	Glume base	6	4	8.9
Triticum monococcum or *T. dicoccum*	Wild einkorn or wild emmer	Glume base	10	6	13.3
*Triticum "*New type"	"New Type" wheat	Glume base	2	1	2.2
Triticum spp.	Wheat	Glume base	5	2	4.4
Legumes					
Pisum sp.	Pea	Seed MNI	8	2	4.4
Lens culinaris	Lentil	Seed MNI	1	1	2.2
Viceae spp. large-seeded	Legume	Seed MNI	72	21	46.7

For full data see *SI Appendix*, Table S4.

Dietary evidence adds further to this picture. Human skeletons have few dental caries, consistent with the limited use of sticky carbohydrate-rich cereal grains in the diet. However, diet spacing between humans and the main meat animals at the sites shown by C and N stable

isotopes (SI Appendix, SI Text 6) suggests plant consumption was more important in the Holocene compared to the Late Glacial contrasting the values from Boncuklu and $10^{th}/9^{th}$ millennium Pınarbaşı with those from the Epipalaeolithic occupation at Pınarbaşı (Table 3). Isotopic evidence shows that plant protein consumption at Boncuklu was similar to the levels found at Çatalhöyük East, but values at both are lower than $10^{th}/9^{th}$ millennium Pınarbaşı, indicating that plant protein was a higher dietary component at the latter site (SI Appendix, SI Text 6). An obvious source for this is the protein rich wild almonds that dominated the botanical assemblages there (Tables 1 and 2), and were probably processed on the numerous, large ground stone tools at Pınarbaşı. This evidence confirms the significance of nut/fruit exploitation as a distinctive contribution to the development of early sedentary behavior on the Anatolian plateau compared with the Levant (21, 33). It also demonstrates dietary differences with contemporary Boncuklu perhaps caused by consumption of fewer fruits/nuts and greater focus on cereals, legumes, low protein tubers and wild plant seeds in the diet, as indicated in the macrofossil remains.

Animal exploitation

At $10^{th}/9^{th}$ millennium Pınarbaşı the hunting of large wild mammals, wild aurochsen especially, dominate the prey spectrum (approximately 34% number of identified specimens - NISP) (Table 4; SI Appendix, SI Text 4) and certainly meat consumption. Sheep and goat are present in relatively high proportions (27% combined) (Table 4), but still lower than at earlier Epipalaeolithic Pınarbaşı (14^{th}–12^{th} millennia cal BC) (22): morphometric analysis is on-going so the domestic/wild status based on morphology is not yet clear. Equids and wild boar have lower representation (7% and 6% respectively — Table 4; SI Appendix, SI Text 4). Fowling and fishing took place, but not as commonly as at earlier Epipalaeolithic Pınarbaşı, or at Boncuklu. Migrant birds were better represented than those that only breed in Central Anatolia, suggesting that fowling targeted aggregated migrating flocks. C and N stable isotope evidence also suggests that the animal protein contribution to Pınarbaşı $10^{th}/9^{th}$ millennium human diets may well have been lower than at either Boncuklu or Çatalhöyük (Table 3; SI Appendix, SI Text 6).

Boncuklu also sees a high representation of wild cattle (Table 4), which would have dominated in terms of meat-yield. Numerically, however, the bones of wild boar (*Sus scrofa*) are most common (45%) (Table 4), contrasting with Pınarbaşı. Both Boncuklu and Pınarbaşı were close to lake and marsh areas, so the high degree of difference in *Sus* exploitation is unlikely to relate only to environmental factors. Rather, for example, it may reflect attempts by Boncuklu's farmers to control wild boar numbers, since these animals are notorious crop robbers. As with plant exploitation divergent hunting practices are seen between these two sites. Sheep and goat representation is another point of difference: the Boncuklu assemblage shows very infrequent presence (Table 4), while their wild/domestic status is uncertain on morphometric grounds. Fowling and fishing are well represented in the Boncuklu fauna, underlining the wetland focus of animal exploitation there. The human C and N stable isotope data from Boncuklu supports higher animal protein contribution to diet, notably from aurochsen and boar (Table 3 and SI Appendix, SI Text 6), with the addition of significant wetland resources such as fish and water birds, relative to $10^{th}/9^{th}$ millennium Pınarbaşı.

Study of the caprine C and N stable isotopes from Pınarbaşı (SI Appendix, SI Text 5) indicates that the diet of the 10th/9th millennium cal BC caprines was very similar to that of the Epipalaeolithic caprines (SI Appendix, Fig. S10). These caprine isotope values contrast with the higher N and varied C3 and C4 plant diet of the morphologically domestic 7th millennium cal BC caprines from Çatalhöyük and Pınarbaşı (SI Appendix, Fig. S10). Given the similarities between Epipalaeolithic and early Holocene caprine diets it is unlikely that the caprines of 10th/9th millennia Pınarbaşı were being managed by humans: the probability is that all caprines were hunted. At Boncuklu however, although some of the caprines have a similar dietary signature to those found at early Pınarbaşı, three of the six caprine bones analysed have higher N, two dramatically higher (SI Appendix, Fig. S11), similar to the later caprines from Çatalhöyük East and West; it is likely that this reflects a diet of marsh, saline and steppe adapted plants, such as might be found on the plain, rather than the classic caprine habitat of the surrounding hills (SI Appendix, SI Text 6). It may also reflect stress in these animals consequent upon management (SI Appendix, SI Text 6). This isotope evidence, along with the presence of a modest amount of herbivore dung on site at Boncuklu, apparently used as fuel and represented by spherulites in soil micromorphological thin-sections (SI Appendix, SI Text 4), raises the possibility of small-scale experimentation with caprine herding close to the site. The scale of this activity and its dietary contribution is likely to have been very small indeed given the faunal assemblage at Boncuklu contains only c. 4% NISP of caprines (Table 4).

	Pınarbaşı Epipalaeolithic $\delta^{15}N$ ‰	$\Delta^{15}N$ diet-human	Pınarbaşı 9th Mill. cal BC $\delta^{15}N$ ‰	$\Delta^{15}N$ diet-human	Boncuklu Höyük $\delta^{15}N$ ‰	$\Delta^{15}N$ diet-human	Çatalhöyük $\delta^{15}N$ ‰	$\Delta^{15}N$ diet-human
Humans	14.8 (n=2)	-	11.8 (n=4)	-	12.3 (n=12)	-	12.7 (n=68)	-
Bos sp.	9.4 (n=2)	5.4	9.8 (n=5)	2.0	9.3 (n=24)	3	9.8 (n=79)	2.9
Sus sp.	-	-	-	-	7.4 (n=7)	4.9	8.0 (n=28)	4.7
Caprines	7.1 (n=22)	7.7	7 (n=10)	4.8	9.6 (n=6)	2.7	9.6 (n=176)	3

Table 3. Nitrogen stable isotope values of samples from human and faunal remains with diet spacing ($\Delta^{15}N$) compared between Pınarbaşı (Epipalaeolithic and 9th millennium cal BC), Boncuklu and Çatalhöyük**.**

Invention, migration or adoption of farming on the Konya Plain?

This evidence allows us to consider the way in which cultivation and herding arrived in the Konya Plain by 8,300 cal BC. While possible, the local development of cultivation seems unlikely as Central Anatolia is outside the historic and recent wild distribution range of several of those cultivars found at Boncuklu including wild emmer wheat and lentil. While einkorn has been considered a possible local domesticate, there is no evidence it was present in central Anatolia in the Late Glacial or early Holocene in the wild, being absent from Epipalaeolithic (22) and earlier 10th/9th millennium Pınarbaşı (30). More probable is that the hulled cereals were introduced to the site, and indeed central Anatolia as a whole, alongside pea and lentil, from those areas in which cultivation was established earlier (2, 33, 35, 39).

Even if locally present, Boncuklu's location – in a wetland area on the plain – is some distance from the habitats in which wild cereals would have grown naturally suggesting local incipient cultivation is unlikely. The situation for small-scale animal husbandry is less clear-cut but seems highly likely. Boncuklu is >15km from the hills in which wild sheep and goat were found and it is possible that local animals were brought into management on the plain from there. An alternative, though one that would be difficult to identify, is that herded stock, like cultivars, were introduced to the site from other regions.

		Pınarbaşı		Boncuklu	
Taxon	English name	NISP	NISP %	NISP	NISP %
Bos primigenius	Aurochs	92	34	169	31
Equus sp.	Equid	18	7	46	9
Large cervid	Deer	3	1	5	1
Dama dama	Fallow deer	0	0	12	2
Sus scrofa	Pig	16	6	258	48
Ovis/Capra	Sheep/goat	53	20	13	2
Ovis sp.	Sheep	17	6	3	1
Capra sp.	Goat	2	1	4	1
Castor fiber	Beaver	1	<1	0	0
Canis sp.	Wolf/dog	0	0	12	2
Vulpes vulpes	Red fox	56	21	13	2
Lepus europeaus	European hare	12	4	4	1
Total		270	100	539	100

Table 4. The relative proportions of mammalian taxa (*Lepus*/hare size and larger) at Pınarbaşı and Boncuklu, expressed as NISP and NISP%.

Material culture and ancient DNA (aDNA) evidence also point to the adoption of cultivation and herding by an indigenous central Anatolian community rather than being brought to the site by incoming farmers from other regions. Among the artefacts, the chipped stone assemblages are very distinctive, being extremely similar through the whole early Holocene occupation sequences at Pınarbaşı and Boncuklu, from the 10th to 8th millennia. Microliths are the principal formal tool type, especially scalene bladelets (Fig. 2), with small flakes being the preponderant debitage (23). Cappadocian obsidian, obtained from 160 km to the east, is the predominant raw material. The assemblages also have clear similarities to local antecedents represented at Epipalaeolithic Pınarbaşı (22, 40) and contrast strongly with the contemporary larger blade and point assemblages seen in the PPNA and early PPNB sites of the Levant and southeast Anatolia (22), the regions from which any migrant farmers would have, of necessity, originated. Thus the lithic evidence suggests that the Boncuklu community was not derived from incoming Levantine or southeastern Anatolian farmer communities, but represent an indigenous forager population. Descent of the 10th-9th millennium populations from earlier local communities, as evidenced at Epipalaeolithic Pınarbaşı, is quite probable. Whilst not conclusive in this regard, recent aDNA results from four individuals at Boncuklu give broad support to this proposition, showing that they derived from a genetically distinct central Anatolian population, contrasting with late Pleistocene and early Holocene Levantine and Iranian populations (41, 42) with low overall genetic diversity, typical of early Eurasian forager populations (43).

In sum, material culture and aDNA evidence suggests that farming was adopted by an indigenous Anatolian forager community obtaining its cultivars from elsewhere, most probably via exchange, which is clearly evidenced at Boncuklu by the presence of Cappadocian obsidian and Mediterranean shell beads (23, 40). Such exchange networks are already well evidenced at Epipalaeolithic Pınarbaşı (21, 22) and those phases at early Holocene Pınarbaşı that predate Boncuklu. Indeed it is worth noting that the obsidian sources, types of Mediterranean shell beads and ground stone sources are the same for both sites in the early Holocene. It is also possible that farming could have travelled with those who moved as part of partner exchanges, suggested for later populations in the aceramic Neolithic of the Konya Plain (44), though the low genetic diversity of Boncuklu's aDNA evidence (43) would suggest any such network was restricted in geographical area.

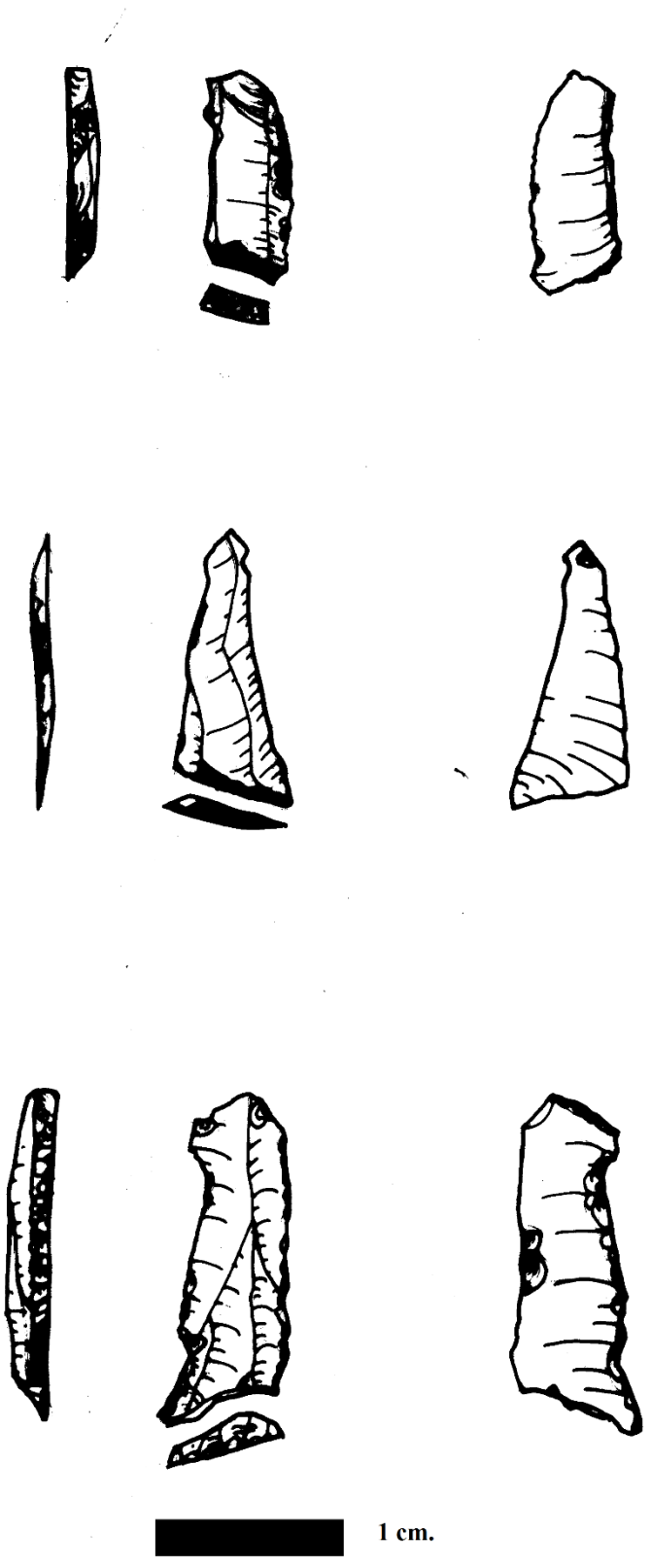

Figure 2 Typical Boncuklu microliths.

Adoption and rejection of small-scale food production in the 9th millennium cal BC Konya Plain

Multiple sources of evidence suggest that, in contrast to Pınarbaşı, Boncuklu saw the uptake of cropping and experimentation with animal management, in both cases on a modest scale. These data provide an archaeological signature for low-level food production (7), where cropping and herding made a small contribution to the food economy of Boncuklu, complementing the foraging activities that are so well represented through its occupation. Cropping at Boncuklu appears to have remained at a modest scale over at least 500 years of the site's occupation between c. 8300 and 7800 cal BC. This persistent low level of cultivation matches the expectations of neither the availability phase nor substitution phase of Zvelebil and Rowley-Conwy' agricultural transition model. Rather, Boncuklu saw long term, stable and small-scale use of crops, with no immediate rapid phase of transformation into a large-scale farming economy. Pınarbaşı, on the other, hand shows no evidence for cultivation of crops at all and appears not to have taken them into its subsistence system. While some consumption of crop products cannot be excluded at Pınarbaşı, archaebotanical, artefact and dietary evidence suggests a major quantitative and qualitative difference in plant acquisition and use when compared to contemporary phases at Boncuklu.

In this context it seems unlikely that experimentation with sheep/goat herding and long-lived, low level cropping had a purely economic motivation, such as an increase in food supply. Even food security and risk reduction seem unlikely motivations in this context, where wetland conditions may have caused challenges for cultivation and whose natural productivity offered a significant diversity of foodstuffs, available through most seasons. It seems unlikely that over-hunting of this or other species, or impacts of small-scale cultivation on local animal biomass, would account for the herding of what must have been very small numbers of caprines (Table 4). The attraction of cropping may have been the development of diversity in plant based foods, perhaps introducing a new range of seed foods that were previously unknown or unutilised Other interests may also have been served in bringing small numbers of caprines in proximity to the community and in taking up cropping, perhaps of a social or symbolic nature. These could have included an interest in displays of control over animals, the consumption of caprine meat in feasts and other contexts, or access to other products that provided materials of both utilitarian and symbolic significance, such as dung, hair, milk, and bone. Cropping may have opened-up new forms of food or beverages, or signified social and cultural ties to other groups in the wider region, well evidenced elsewhere in the artefact record of exchange and interaction (23, 40, 46). Farming may also have been of interest because of the opportunities for social distinctiveness it created for particular households, as seen in the use of diverse household symbolic practices at Boncuklu (47).

Relationships between the sites of Pınarbaşı, Boncuklu and Çatalhöyük

A major issue in understanding the implications of this evidence for the spread of farming is the relationship between the occupants of Boncuklu and Pınarbaşı during the period c. 8,300–

7,800 cal BC when both sites were occupied. It is important to establish if the sites were home to separate communities or a single community that used and moved between both settlements. Seasonality evidence (Fig. 3) is crucial in this regard.

At Pınarbaşı the birds, studied by N.R., include many year round residents, spring and autumn migrants, along with over-wintering birds which are better represented than those that only breed in Central Anatolia. Fowling probably concentrated on the more aggregated migrating flocks. It is possible that the majority of birds found were taken during March and April, but such a restricted time period seems unlikely, given the range of species and number of birds represented at Pınarbaşı. Thus the Pınarbaşı avifauna evidence more likely suggests occupation October–April, with quite possibly additional months represented in the record. The majority of birds from Boncuklu, studied by Y.E., were wetland birds which could be divided into seasonal migrants, year–around residents and visitors. The recorded numbers indicate a strong exploitation of overwintering flocks but with spring, early summer and autumn visitors also targeted to a lesser extent. Indeed, one young bird at c.6 months after hatching could be assigned to early autumn based on the spongy, undifferentiated end of the tibiotarsus. These observations support occupation at Boncuklu from September/October through to April, but do not discount the possibility that birds were exploited for a greater part of the year.

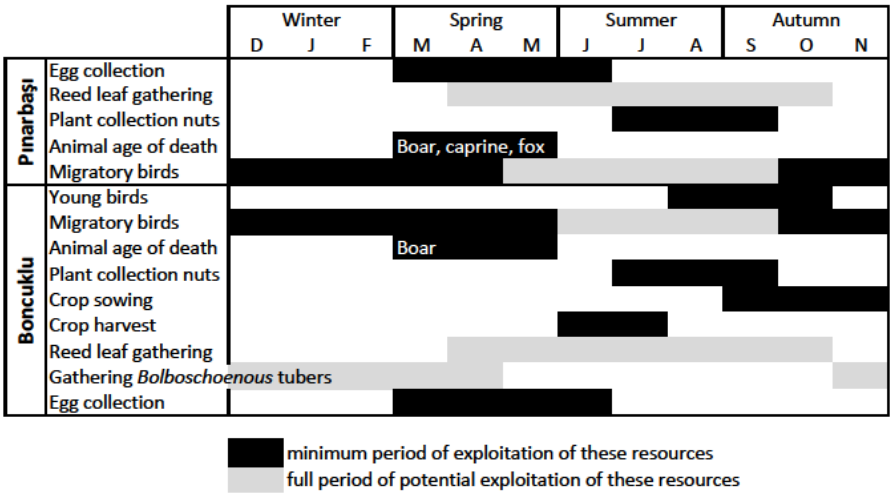

Figure 3 Indicators of the seasonality of exploitation of particular animal and plant resources on the sites at Pınarbaşı and Boncuklu.

Other seasonally specific resource exploitation evidence common at the sites is indicated in Fig. 3 and demonstrates occupation for most of the year, supporting our view that the communities were sedentary for significant periods. It is notable that the seasons where there is very strong evidence of activity at Boncuklu are also, for the most part, the seasons well represented in the fauna and flora at Pınarbaşı. The only season when evidence for resource exploitation is not clear at Pınarbaşı is late autumn to early winter, but it is likely that winter fowling covers much of this period at Pınarbaşı, as well as at Boncuklu.

There are other contrasts in social and material practices that suggest that we are looking at distinct communities with their own distinctive identities. A range of more elaborate bead and ornament types are found at Boncuklu, but not at Pınarbaşı (46). Pınarbaşı houses had wattle and daub superstructures (21). The walls of Boncuklu buildings are constructed of mudbrick and the buildings have distinctive internal arrangements, with 'cleaner' slightly raised southeastern floor areas and 'dirtier', northwestern kitchen areas around the main hearth (Fig. 4). These arrangements reflect a structured and repetitive use of domestic space not seen at Pınarbaşı and prefigure practices at Çatalhöyük with its north/south division between 'clean' and 'dirty' areas in houses (10). Many of the Boncuklu dead were buried under the 'clean' area of the houses during their occupation (47), as at Çatalhöyük East, a practice not documented at Pınarbaşı where burials seem to have taken place outside buildings, possibly in small cemetery areas (21). There is also greater evidence for ritual and symbolic practice in the buildings at Boncuklu compared to Pınarbaşı. At Boncuklu the 'clean' areas of the houses were idiosyncratically decorated with paint and saw the incorporation of animal bones, especially wild aurochs horns and skulls into the walls and floors (47). Boncuklu's buildings are repeatedly reconstructed on the same location, over the ancestral dead and ancestral house(s), also prefiguring practices at Çatalhöyük, and demonstrate a more institutionalised social role for households than is apparent in communities such as those at Pınarbaşı (47).

Figure 6 Typical Boncuklu domestic building.

Therefore, we think it highly unlikely that the groups at Pınarbaşı and Boncuklu belonged to a single co-resident community, who moved between two settlement locales, despite the probability of links and interactions between these communities. The highly structured use of domestic space at Boncuklu, with associated ritual and symbolic practices seems directly antecedent to very similar practices at Çatalhöyük East. This forcefully suggests that the community at Boncuklu was a direct antecedent to that at Çatalhöyük East, although not necessarily the only one (44), unlike Pınarbaşı, whose occupation ended around 7,800 cal BC.

Discussion and conclusions

Analysis of chronological, material culture and seasonality evidence demonstrates that the Konya Plain of central Anatolia was home to contemporary settlements in the later 9th and early 8th millennium cal BC, occupied by two communities with quite distinctive cultural identities. Though located in broadly similar environments, the two communities made contrasting economic choices: the Boncuklu community adopted and sustained low-level crop cultivation and developed animal management; the Pınarbaşı community rejected both. These settlements maintained their cultural and economic distinctiveness for 300-500 years, despite plentiful evidence of shared technologies and participation in the same exchange networks with the same obsidian sources and a similar range of marine shells. Contemporary Aşıklı, 150kms to the east, appears to provide a further contrast, with a more substantial mixed farming economy including a wide range of crops and significant investment in herding (8, 36, 37). The fuller publication of the early phases from Aşıklı will allow even more thorough analysis of these contrasts. Together the evidence shows that in central Anatolia's first phase of farming, during the late 9th and early 8th millennium BC, there was an economic mosaic with a network of settlements, connected by exchange and other interactions, supported by different food procurement strategies. Notably, Boncuklu households demonstrated strong evidence of highly structured domestic behaviours incorporating a major role for symbolic and ritual practices in contrast to Pınarbaşı households. The evidence demonstrates that during the early spread of farming beyond the Fertile Crescent not only did low-level food production persist for centuries in such contexts, but it was associated with distinct ritual, symbolic and social practices and thus bound up with community identities.

The first phase of farming in the Konya Plain occurred in the second half of the 9th millennium cal BC through the adoption of cultivation and probably experimentation with herding by indigenous foragers. Clearly, this is at odds with explanations that have attributed farming emergence beyond the Fertile Crescent to the demographic expansion of farmers from that region (3, 4, 11, 19). Evidence does not support a large-scale demographic transition model, and while the archaeological evidence does not preclude the movement of modest numbers of individuals to and fro between central Anatolia and those areas with farming communities to the south and east, the initial aDNA evidence suggests that Boncuklu's community was a genetically limited pool (42), distinct from the Levantine Neolithic communities (41) and perhaps, thus, even small scale movements of people were also not very frequent. It should be pointed out that these statements relate to the initial phase

of farming in central Anatolia and the evidence does not exclude later episodes of farmer colonisation or smaller scale population exchanges, the latter of which has been supported by contrast of the Boncuklu population's genetic record to those from later Neolithic sites in central and western Anatolia (42). Rather than be propelled by demic diffusion cultivation was adopted at Boncuklu from c. 8,300 cal BC as a sustained endeavour used on a small-scale, in absolute terms and relative to other food acquisition practices. Animal husbandry was also used as part of a range of low-level food production practices. These practices developed in a context where the social and symbolic significance of herding and cultivation might have been more important than their productive economic value, at least in the initial stages of their adoption.

These observations are important for further understanding both the substantive history of early farming development in Eurasia and its core theory. Cultivation and herding did not arrive on the Konya Plain with a 'big bang' but through the introduction of a limited range of plants and animals produced in small quantities. That such low-level food production was stable for at least 300 years does not fit the definition of a 'substitution phase' in existing European-focused models of farming transition, those that envisage the existence of 'farming frontiers' during which a rapid transition to larger-scale food production occurs (12). This contrast may reflect the distinct circumstances that pertained in areas fringing the Fertile Crescent in the millennia during which sedentism and farming emerged. There was no 'frontier' as such in the Konya region, with incoming farmers absent from its archaeological record, and local indigenous communities responding in diverse and complex ways to the availability of crops and the option of herding animals enabled through their wide-reaching exchange and communication networks.

The uptake of food production within a tightly bound set of cultural practices, appears, thus, to have contributed to the long-term success and perpetuation of the Boncuklu community, and thus may well have provided an important factor in its survival into the mid-8th millennium and its continuities, probably of population and certainly of social practices, with the community at Çatalhöyük East. Economically, cropping and herding diversified the range of available foods and added some whose production could be increased if required. Beyond that adoption of farming appears to have had significant social consequences for households at Boncuklu when we consider the major differences between Boncuklu houses and those at Pınarbaşı, where the community rejected farming and apparently continued long standing pre-existing social practices and household behaviours. This is expressed in more intense house-based ritual and symbolic practices, increasingly structured use of domestic space, as well as in the character of and continuities in households at Boncuklu. These factors clearly promoted social stability. Economically the long phase of low-level food production at Boncuklu provided the foundation for a major transition to large mixed-farming-reliant communities in central Anatolia following c. 7800 cal BC as ultimately represented in the local sequence by Çatalhöyük East. The pace of such changes remain to be demonstrated by further research and it is an open question as to whether this transition from low level food production to large scale mixed farming was a rapid step change or slow and incremental.

The persistence of foraging and rejection of farming at Pınarbaşı is also worthy of further consideration. Pınarbaşı's longevity as a settlement locale in the early Holocene appears to have been based on hunting of wild mammals, wetland exploitation and significant focus on nut exploitation, all afforded by its ecotonal setting between the hills, plain and wetland. Perhaps this existing diversity, including nutritious storable plant resources, was a key factor in a lack of interest in adopting cultivation. Another factor may have been a conscious desire to maintain traditional identities and long standing distinctions with other communities, in part reflected in its particular way of life and its specific connections with particular elements in landscape, for example the almond and terebinth woodlands whose harvests underwrote the continuity of the Pınarbaşı settlement.

The variability in response to the possibilities of early food production in a relatively small geographical area demonstrated here is notable and provides an example useful in evaluating the spread of farming in other regions. It shows the possible role of indigenous foragers, the potential patchwork and diffuse nature of the spread of farming, the lack of homogeneity likely in the communities caught up in the process, the probability of significant continuities in local cultural traditions within the process and the potentially long term stable adaptation offered by low level food production. The strength of identities linked to exploitation of particular foods and particular parts of the landscape may have been a major factor in contribution to rejection or adoption of food production by indigenous foragers.

The results are also relevant for understanding the processes that underpinned the initial development of farming within the Fertile Crescent itself, that is the region in which the wild progenitors of the Old World founder crops and stock animals are found. Recent research has rejected the notion of a core area for farming's first appearance in southwest Asia and demonstrated that farming developed in diverse ways over the Fertile Crescent zone from the southern Levant to the Zagros, very analogous to the situation just described for Central Anatolia (2). Cultivation, herding and domestication developed in that region, and it seems inescapable that exchange of crops and herded animals occurred between communities (2) involving a spread of farming within the Fertile Crescent, leading eventually to the Neolithic farming 'package' that was so similar across the region and which spread into Europe (5). Central Anatolia was clearly linked to the Fertile Crescent with significant evidence of exchange and some shared cultural traditions from at least the Epipalaeolithic (22). The evidence presented here demonstrates very clearly the movement of crops between settlements and regions in early phases of the Neolithic through exchange and thus allows us to identify episodes of crop exchange that were probably taking place within the Fertile Crescent itself, but are difficult, if not impossible, to distinguish due to the presence of crop progenitors across much of the region.

In conclusion, we show that contextually specific explanations for the movement of farming are necessary and should not rely on either simple demographic movement scenarios, on an assumption of homogeneous responses to farming availability in regions, on assumptions of the existence of strongly bounded 'farming frontiers' or models from other regions that may not be relevant to the local social, cultural and economic circumstances. In addition, we have

provided insights into the consequences of the adoption of food production for forager communities so involved, demonstrating that the early spread of agriculture, like its initial development in the Fertile Crescent, was an extended and variable affair embedded in the social connections and regional exchange networks of the early Holocene rather than driven purely by economic advantage and subsistence concerns.

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Supplemental Information Appendix

SI Text 1: C14 dating of Boncuklu and Pınarbaşı

Douglas Baird, Andrew Fairbairn, Ofer Bar-Yosef, Geraldine Jacobsen, Xiaohong Wu

Pınarbaşı

AMS radiocarbon results were assayed from excavation trenches A and D at Pınarbaşı (Fig. S1), sampling similar prehistoric settlement stratigraphy c. 25m apart. Radiocarbon results reported elsewhere (1) were supplemented by additional results to help determine the age span of the excavated sequences and their chronological relationship to Boncuklu. In Area A earlier deposits remain unexcavated.

Area A

In contrast with Boncuklu only a few samples for C14 were *in situ* components of the stratigraphy, with many of the excavated contexts consisting of midden. As we mainly dated a series of small short life samples of seeds/nutshell, residual material is a potential issue for our Bayesian modeling (all modelling, diagram production and data generation was undertaken using Oxcal 4.2 (2) using IntCal13 atmospheric curve (3)), as was intrusion from later deposits (1). With one exception, all of the dates from Area A were from short life nutshell fragments, the other being from an *in situ* human burial (ZAN). Two broad early and late sample groups were used in a Bayesian contiguous phase model. The upper phase, included samples from an extensive and potentially long-lasting series of middens (ADK/ADN) overlying Building 5, a burial (ZAN) and floors/structure deposits, with middens and occupation spreads sampled in the lower phase. The model showed good overall agreement (99.5), with high convergence values in all samples. The lowest dated deposits in Pınarbaşı Area A were accumulated between 9308-8801 cal BC (95.4% probability), probably 9070-8831 cal BC (68.2% probability) (Fig. S3). It should be noted that this is not the earliest deposit or phase in this trench or on the early Holocene mound at the site and these estimates provide a *terminus ante quem* for occupation in the area. The late phase at Pınarbaşı ended 8164-7395 cal BC (95.4% probability), probably 8128-7582 cal BC (68.2% probability). The late phase end date was greatly affected by OZH786, which is c.200 radiocarbon years later than the other samples from the upper middens and extends the occupation well into the 8th millennium cal BC. Removal of that sample pushes the termination of the late phase at 8197-7665 cal BC (95.4% probability), probably 8162-7923 cal BC (68.2% probability).

Area D

Four AMS dates were assayed from Area D, the lowest from DGS being a deposit associated with a burial and below Building 3. Dates from Building 3 post-date this, including from a floor in Building 3, context DCX, that contained *in situ* artefacts, and two contexts from a series of deposits dumped into the shell of Building 3, namely DCP and DCL. A short Bayesian sequential phase model sought to refine the chronology across this sequence (Fig S2). DGS was clearly occupied over a millennium before the upper deposits in Building 3, with the modelled dates showing deposition around the Pleistocene/Holocene boundary at 9799-9406 cal BC (95.4% probability), probably 9737-9451 cal BC (68.2% probability). This

date significantly pushes back Holocene human occupation in central Anatolia, to the very earliest part of the Holocene, bringing it much closer to the Epipalaeolithic occupation in the rock shelter at Pınarbaşı, excavated in Area B (4). The later dates are all within the range 8300-7800 cal BC. The model showed the Building 3 floor was dated to between 8214-7953 cal BC (95.4% probability), probably 8187-8118 cal BC (68.2%) with the fills starting at 8155-7846 cal BC (95.4% probability), probably 8120-7956 cal BC (64.2% probability), and ending by 8137-7590 cal BC (95.4% probability), probably 8046-7788 cal BC (68.2% probability).

Boncuklu

The Boncuklu chronology presented here includes the largest set of C14 dates currently available for one excavation trench at Boncuklu - from Area H (Fig. S4). The nine AMS dates spanned the calibrated range from 7966-7754 cal BC (95.4% probability) to 8434-8250 cal BC ((95.4% probability). A sequential phase Bayesian model was run (Oxcal 4.2 using Intcal13) to improve the resolution of both the establishment and end dates of the excavated sequence (Fig. S5). Priors were produced by the stratigraphical sequence which includes a series of inter-stratified midden deposits, buildings and burial cuts, whose stratigraphic relationships were clearly established. An emmer spikelet fork from a midden deposit HQP represents the earliest phase in H that has a dated sample and almost certainly stratigraphically predates Building 14. From Building 14 we have 4 *in situ* burials, placed under the floor of this building during the life of the structure, with dates on human bone from the articulated skeletons, ZHP, ZHJ, ZHF, and ZHAF. Overlying Building 14 was a successor building, Building 5 and the shell of this structure was filled with a series of accumulating midden deposits. From this phase of accumulating midden in Building 5 almond nutshell samples were dated in HFN and HFI. Further midden deposits accumulated over Building 5 and this phase is represented by a sample of human bone in midden HTG, deposited as an individual item, not as part of an articulated burial. HTG was cut into by the foundation for Building 4. One of the first acts in the construction of Building 4 was to place a double bucranium in the wall foundation. This *in situ* emplacement is, therefore, definitely later than HTG and is represented by a date on the aurochs bucranium HLM. These dates are, therefore, all obtained from plant remains that grew for a single year or human and animals that lived from a few years to a few decades. Whilst only some elements are definitively *in situ* and redeposition is a possibility for the plant remains and the individual human bone in HTG, all of the samples demonstrated a high concordance values, with an overall agreement index of 106.6, suggesting that this was not the case and that this model has broad scale validity.

This Area H model clearly indicates that the earliest excavated deposits in Area H were deposited between 8462-8271 cal BC (95.4% probability), probably between 8354-8283 cal BC (68.2% probability). The sequence ended between 7952-7711 cal BC (95.4% probability), probably between 7904-7781 cal BC (68.2% probability). We have excavated buildings in Area H earlier than the oldest phases included in Figure S5 and there are also deposits that precede the earliest structure. Thus the earliest date so far for Boncuklu definitively does not represent the beginning of the occupation at the site, rather providing a *terminus ante quem* for settlement. Likewise, we have strong reasons to believe that we have in situ deposits in other trenches that postdate the latest dated element of the sequence in Area H. As we have stated in the main text, it is also the case that the latest Neolithic levels at Boncuklu were subject to erosion and damage and therefore the site occupation certainly continued after the latest Neolithic deposits excavated on the top of the mound.

Acknowledgements: Ofer Bar-Yosef and Xiaohong Wu provided dates through the Peking University accelerator and Geraldine Jacobsen through the Australian Institute for Nuclear Science and Engineering accelerator. The ORADS scheme provided dates from Pınarbaşı from the Oxford accelerator. Dating was also made possible due to funding from grants acknowledged in the main text acknowledgements.

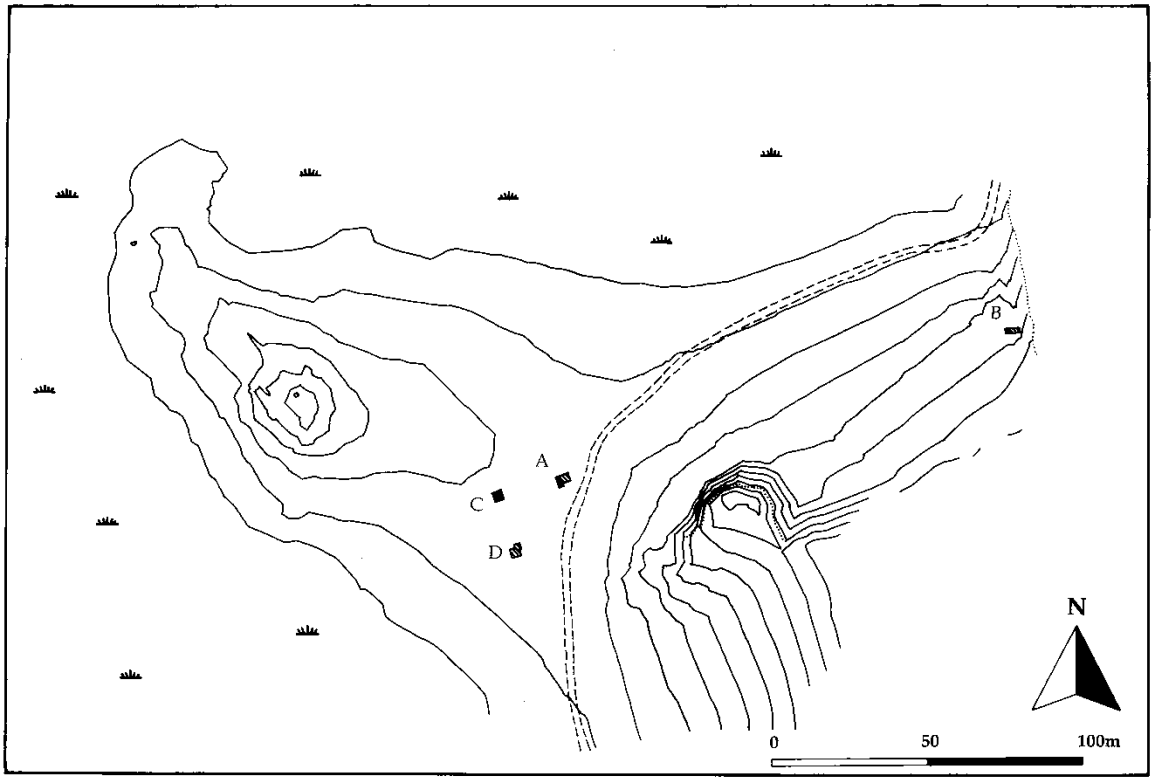

Figure S1 Site plan of Pınarbaşı showing main trenches excavated.

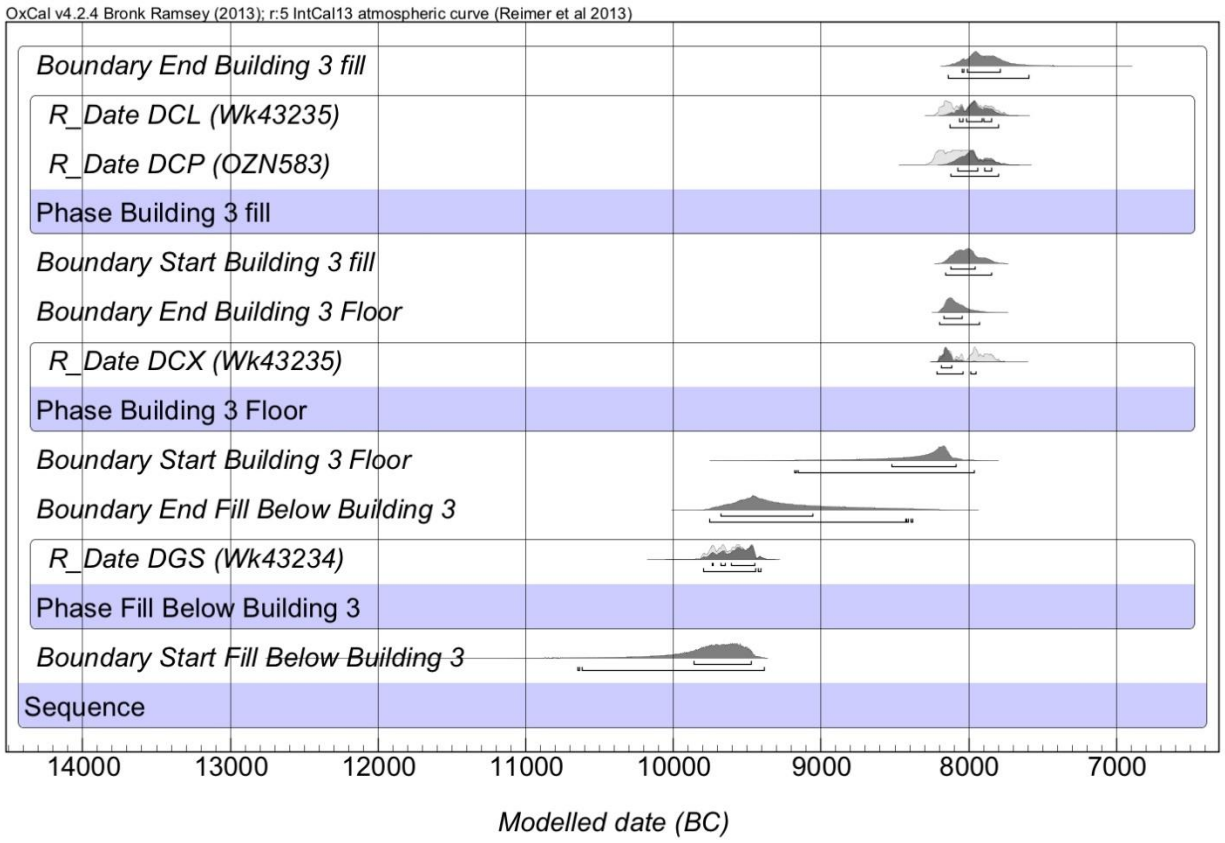

Figure S2 Bayesian model of C14 dates from Pınarbaşı Area D.

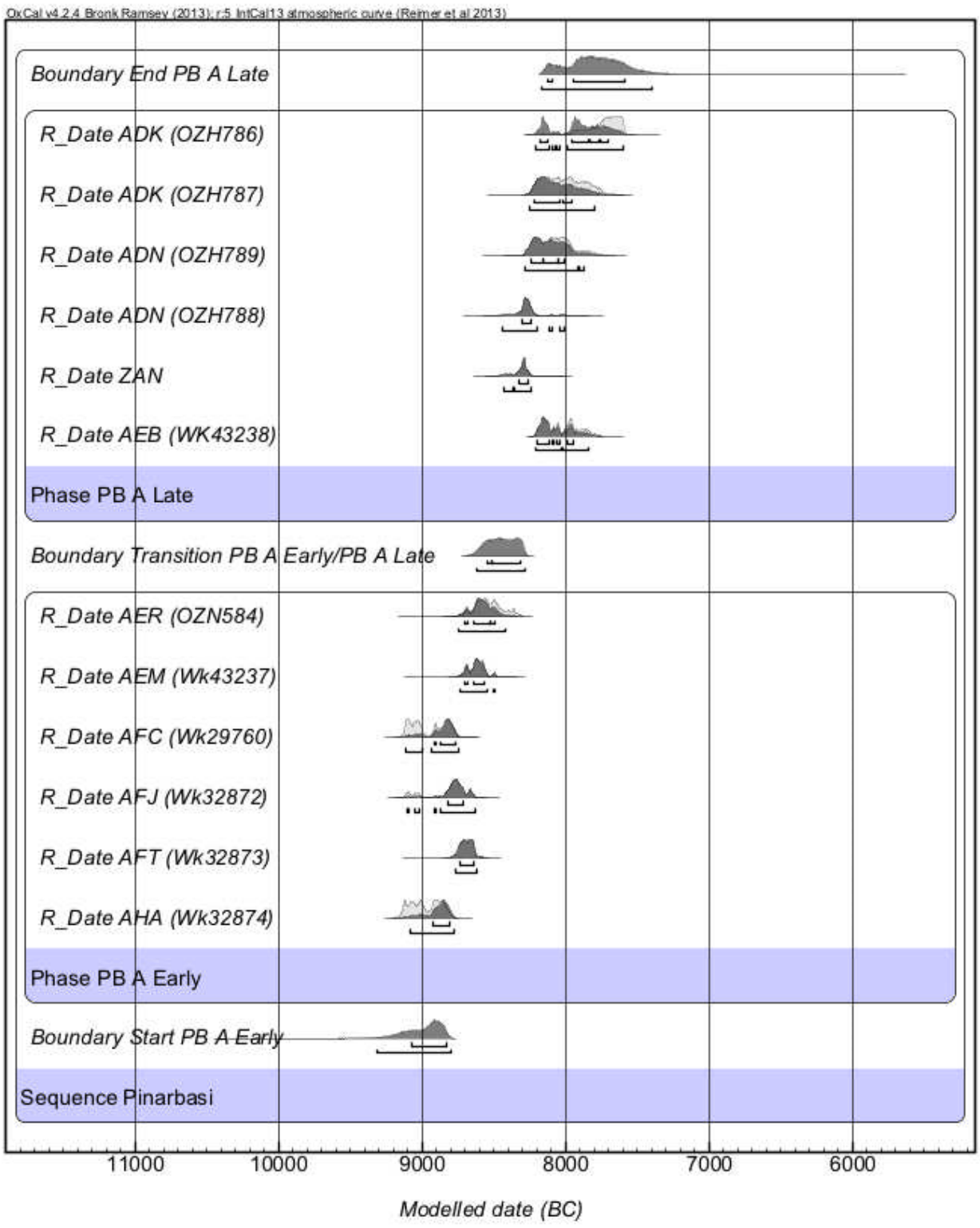

Figure S3 Bayesian model of C14 dates from Pınarbaşı Area A

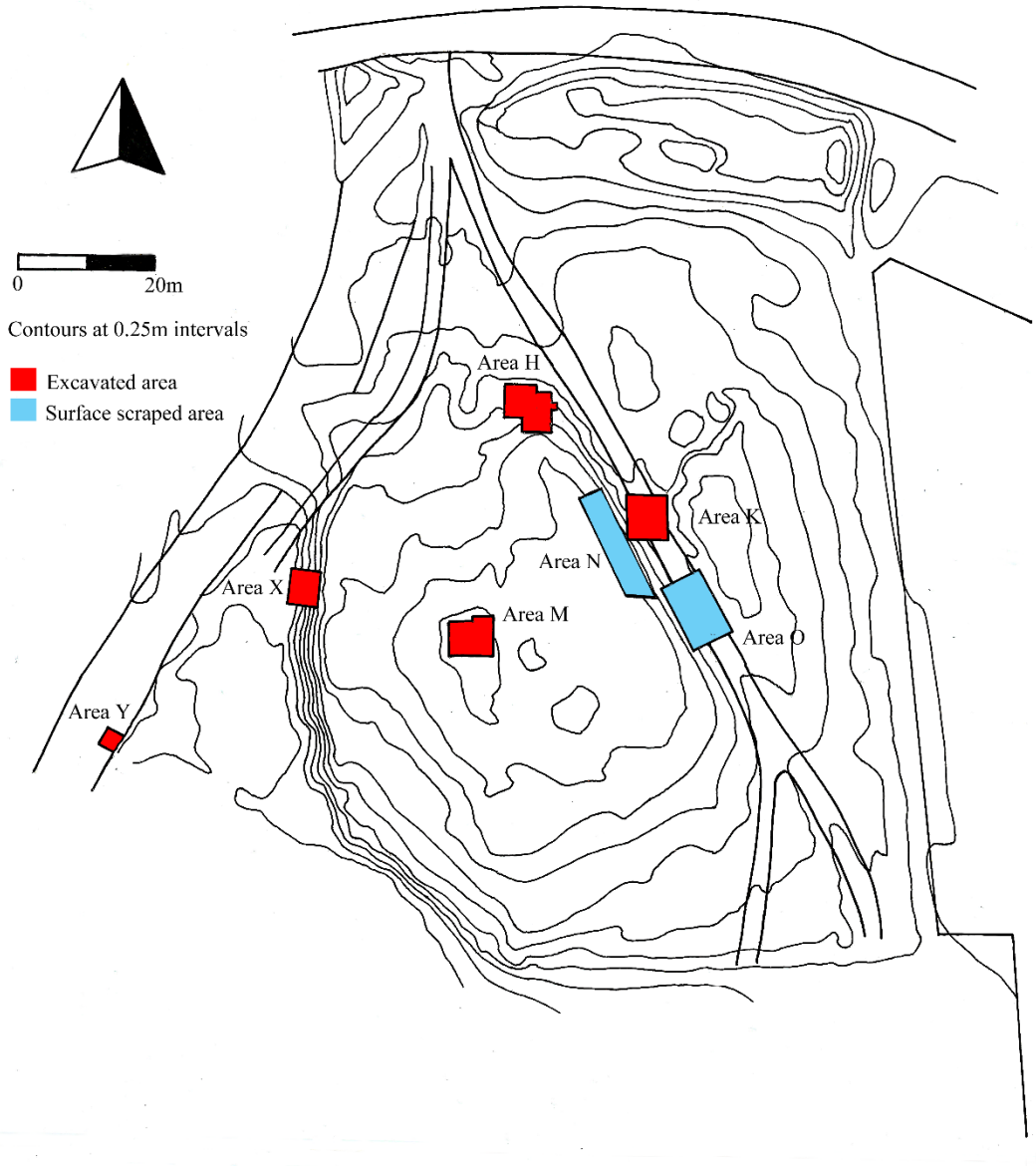

Figure S4. Site plan of Boncuklu showing main excavated trenches.

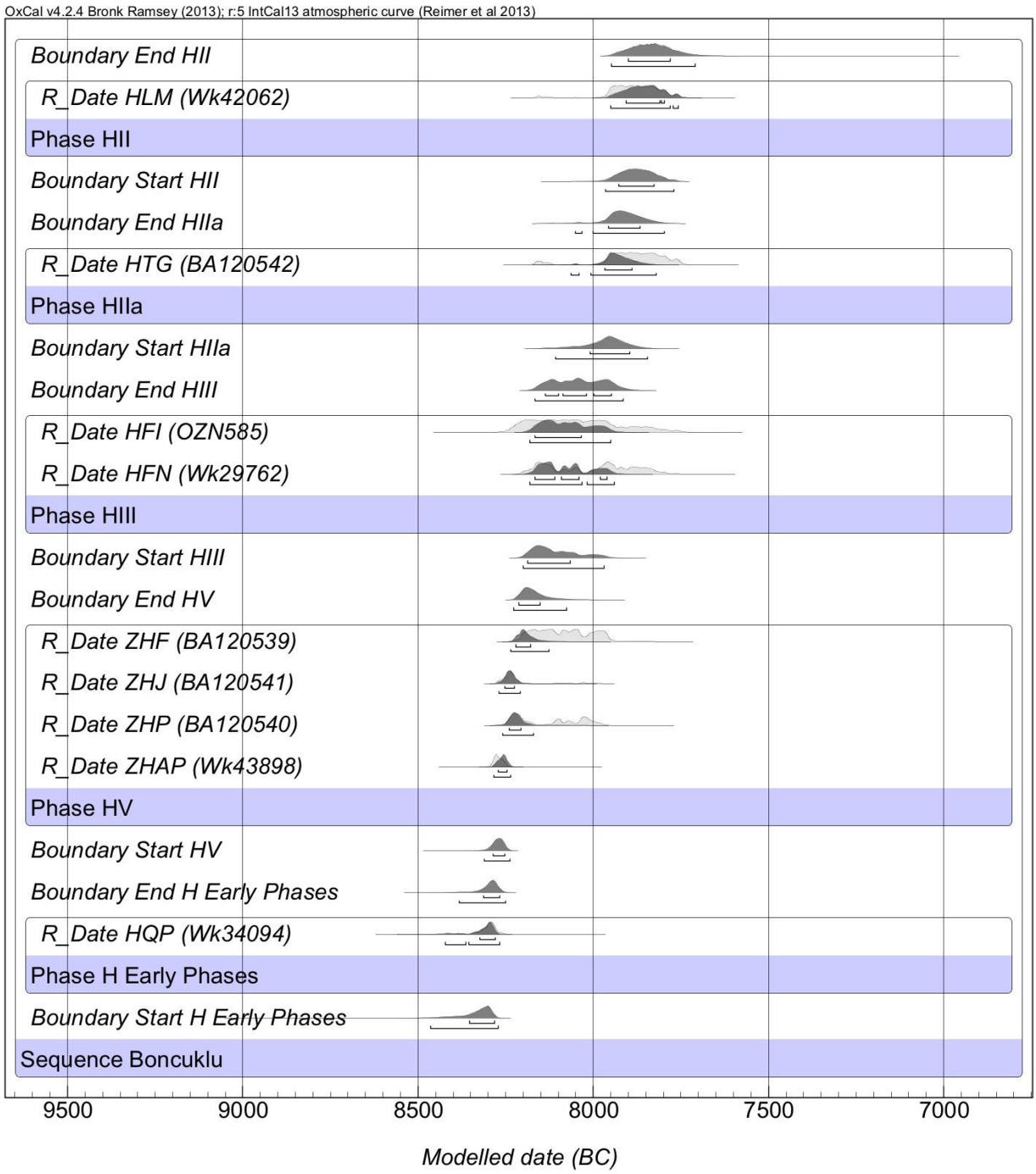

Figure S5 Bayesian model of C14 dates from Boncuklu Area H.

	Modelled cal (BC) 1σ	Modelled cal (BC) 2σ	A	C
Boundary End Late Phase	*8128-7582*	*8164-7395*		97
R_Date ADK (OZH786)	8173-7699	8205-7600	49.3	99.3
R_Date ADK (OZH787)	8221-7954	8245-7796	105	99.8
R_Date ADN (OZH789)	8242-8007	8281-7867	103.3	99.8
R_Date ADN (OZH788)	8303-8236	8439-8003	105.6	99.9
R_Date ZAN (OxA-16584)	8320-8261	8425-8240	107.1	99.9
R_Date AEB (Wk43238)	8199-7945	8208-7839	105.1	99.8
Transition Late to Early	*8541-8308*	*8620-8281*		99.8
R_Date AER (OZN584)	8697-8488	8746-8421	103.5	99.9
R_Date AEM (Wk43237)	8700-8563	8736-8491	100.4	99.9
R_Date AFC (Wk29760)	8913-8765	9116-8746	96.8	99.9
R_Date AFJ (Wk32872)	8816-8710	9103-8630	109.9	99.9
R_Date AFT (Wk32873)	8729-8640	8770-8619	99.9	99.9
R_Date AHA (Wk32874)	8922-8802	9082-8779	97.2	99.9
Boundary Start Early	*9070-8831*	*9308-8801*		98.2
Indices: Amodel 88.6; Aoverall 89.6				

Table S1 Contiguous Phase Bayesian model for AMS dates from Pınarbaşı Area A

	Modelled cal (BC) 1σ	Modelled cal (BC) 2σ	A	C
Boundary End Building 3 Fill	8046-7788	8137-7590		98.1
R_Date DCL (Wk34089)	8063-7843	8127-7796	97.9	99.6
R_Date DCP (OZN583)	8073-7846	8123-7798	84.4	99.6
Boundary Start Building 3 Fill	8120-7956	8155-7846		99.7
Boundary End Building 3 Floor	8167-8044	8198-7930		99.9
R_Date DCX (Wk43235)	8187-8118	8214-7953	108.2	99.9
Boundary Start Building 3 Floor	8522-8086	9178-7953		99.1
Boundary End Fill Below Building 3	9678-9056	9755-8382		99.1
R_Date DGS (Wk43234)	9737-9451	9799-9406	99.4	99.8
Boundary Start Fill Below Building 3	9861-9473	10649-9388		95.6
Indices: Amodel 95.2; Aoverall 94.3				

Table S2 Contiguous Phase Bayesian model for AMS dates from Pınarbaşı Area D

	Modelled cal (BC) 1σ	Modelled cal (BC) 2σ	A	C
Boundary End HII	7904-7781	7952-7711		96.8
R_Date HLM (Wk42062)	7907-7797	7952-7758	101.9	99.3
Boundary Start HII	7930-7828	7967-7773		99.5
Boundary End HIIa	7956-7867	8053-7797		99.5
R_Date HTG (PKUAMS120542)	7968-7888	8063-7823	101.2	99.5
Boundary Start HIIa	8009-7896	8131-7848		99.4
Boundary End HIII	8141-7947	8167-7916		99.2
R_Date HFI (OZN585)	8168-8035	8182-7951	117.7	99.3
R_Date HFN (Wk29762)	8167-7961	8182-7941	100.9	99.3
Boundary Start HIII	8189-8063	8201-7970		99.5
Boundary End HV	8213-8152	8230-8074		99.8
R_Date ZHF (PKUAMS 120539)	8222-8179	8236-8129	79.6	99.9
R_Date ZHJ (PKUAMS 120541)	8252-8225	8269-8210	113	100
R_Date ZHP (PKUAMS 120540)	8241-8206	8260-8171	133.8	99.9
R_Date ZHAP (Wk43898)	8271-8246	8285-8235	76.8	99.8
Boundary Start HV	8287-8253	8311-8238		99.9
Boundary End H Early Phases	8312-8267	8381-8251		99.6
R_Date HQP (Wk34094)	8324-8279	8423-8267	107	99.3
Boundary Start H Early Phases	8354-8283	8462-8271		97.9
Indices: Amodel 102.2; Aoverall 105.6				

Table S3 Contiguous Phase Bayesian model for AMS dates from Boncuklu Area H

SI Text 2: **Macrofossil evidence of plant food exploitation at Boncuklu**
Andrew S. Fairbairn

Intensive flotation and wet sieving using a SMAP type flotation machine, recovered a rich archaeobotanical assemblage of charred plant remains from 50-100% of soil recovered from all excavated undisturbed prehistoric contexts at Boncuklu. Full analysis of 45 contexts from Areas H, K, M, N and P recovered 36,060 seeds and other plant remains from 3184 litres of processed soil (Table S4). The sample set included a range of content types, from middens, structural debris and floor construction layers, making up much of the site's volume, to occupation lenses, hearths and stakehole fills, some of the few contexts within buildings that retained material *in situ*. No *in situ* storage deposits were recovered.

Archaeobotanical remains were mainly charred, mixed with some seeds that naturally resist decay (e.g. hackberry (*Celtis*) stones and silica rich *Lithospermum* species (Table S4). While preserved in all contexts, with larger contexts typically having many seeds, plant macrofossils were not present in high volumes, as shown in the median assemblage density (grams of plant material per litre of excavated soil) of 0.014 (Table S4), less than 10% of the value at Çatalhöyük East (5), but greater than the value of 0.001 from Pınarbaşı (1). The composition of samples by weight (Fig. S6) was dominated by the remains of wild seeds (32.6%) and vegetative plant parts, such as fragments of charred reed culm/stem (13.8%), tuber (17.3%) and rhizome fragments (22.0%). Remains of probable cultivars, such as cereal and legume remains comprised a small proportion of the assemblage (1.1%) with charred nutshell forming 2.3%. Unexpectedly, wood was rarely the dominant sample component, forming 9.2% of the assemblage by weight. Plant remain assemblages usually contain the remains of plant foods mixed with fuel remains. Boncuklu evidence suggests wood was a minor element of the fuel mix, with perhaps vegetative materials such as reed stems being a key fuel component, consistent with phytolith evidence (SI Text 3). It is possible that many of the seeds, among them fully aquatic species and many wetland taxa (sum = 23,505 representing 66.3% of the assemblage), may have derived in part from this mixed fuel source.

Cereal remains

Only 69 cereal remains (NISP), forming 0.2% of the seed assemblage, were identified in secure Neolithic contexts deriving from 42% of the sampled contexts (Table S4). Cereal remains were always very sparse, even in otherwise abundant seed assemblages. Glume wheat seed and chaff remains made up all of the identified Neolithic assemblage, their antiquity was verified by direct dating of two chaff (spikelet fork) specimens, one each of emmer (Wk34094: 9107±39 BP (8434-8250 cal BC 2σ)) and einkorn (Wk34093: 9054±38 BP (8305-8250 cal BC 2σ)). Cultivated barley was not found in Neolithic contexts, with previously reported remains (6) deriving from an Ottoman (post-Medieval) oven and intrusive in Neolithic midden deposits in the upper part of the stratigraphy, including many free-threshing wheat remains, notably hexaploid rachis segments. The wild barley found at site was from wall barley (*Hordeum murinum*) and related weedy types and not *Hordeum spontaneum*, the progenitor of the cultivated species.

Glume wheat species have a great deal of overlap in their morphology, making identification of species and domestic status difficult, a task further complicated at Boncuklu by poor preservation and fragmentation (Fig. S7). Both emmer (*Triticum dicoccoides/T. dicoccum*) and einkorn (*Triticum boeoticum/T. monococcum*) grains were present, including grains with

rounded apices, flat ventral surface and low dorsal ridge similar to wild emmer (Fig. S7a), though there was overlap with the morphology of 'New Type' glume wheat grains recently described in detail at Çatalhöyük East (7). Several grains were well beyond the expected size range for wild emmer (Fig. S7b; Fig. S8) and probably represent cultivated forms (see ref. 8 for terminology). Einkorn was clearly identified by the presence of numerous fragments of laterally compressed grains, with sharply pointed proximal and distal poles and convex dorsal and ventral surfaces including highly compressed narrow forms (Fig. S7d) and broader forms (Fig. S7e), possibly derived from wild and cultivated forms respectively. A number of specimens were probably emmer (Fig. S7c). Measurements of the few grains and grain fragments preserving both breadth and thickness – considered key for distinguishing species – show forms ranging across the wild and cultivated/domestic size ranges (Fig. S8).

Spikelet forks and glume bases of einkorn and emmer wheat were also found through the site deposits in small quantities and again were badly damaged, often missing key identification features. A small number of distinctive emmer spikelet forks were identified characterized by large size, low glume insertions, smaller, rounded rachis internode scar, less developed secondary keels and tertiary veins present on the glume surfaces (Fig. S7g-j). Einkorn was also present, its spikelet forks with high glume insertion (parallel to the rachis scar) and well developed primary and secondary keels (Fig. S7h). In most cases damage to the rachis attachment scar precluded identification of domestic status (see 9 for discussion of this issue). Two complete spikelet forks from the 'New Type' glume wheat were present in samples from Area H, characterized by their robust glume venation (primary, secondary and tertiary veins) and glume insertions parallel to a rounded rachis scar (Fig. S7k,l). Three specimens showed clear evidence of a domestic type rachis attachment scar, two non-basal emmer spikelet forks (Fig. S7 h and i) and one basal spikelet fork of 'New Type' wheat. The rachis internode scars of all other emmer specimens were ripped/'tear-off' types that defy categorisation as wild or domestic (8, 9). While no undamaged wild type spikelet forks were identified several emmer specimens lacked the projection above the rachis scar indicative of domestic types (10).

In summary the assemblage confirms the presence of einkorn and emmer wheat, including wild sized grains and possible wild type spikelet forks, with a small number of domestic type emmer spikelet forks mixed with damaged specimens and also larger cultivated type grains. 'New Type' wheat chaff is present, including one with a domestic type scar, though as it is sub-basal this could have derived from a wild population. This type of assemblage, with a mix of domesticated and wild forms, is found for several millennia in the Aceramic Neolithic, contemporary and earlier than Boncuklu in the Levant (8). The preservation is such that the overall proportion of wild:domestic types is meaningless and a larger sample size is required to provide those data. It is impossible at present to fit the site into the regional pattern of change in crops from wild to domestic taxa (see ref. 8 - Table S6). With Aşıklı Höyük (9) the Boncuklu remains provide the earliest evidence for cereal exploitation in central Anatolia. The presence of grains and chaff suggests that crop processing was undertaken at the site, activity also supported by the phytolith analysis (SI Text 3) and a weed flora which also indicates cultivation (see below).

Large-seeded legumes

Large-seeded legumes were more abundant in the Boncuklu assemblages than the cereal remains, though still a small part of the assemblage (0.85%). A single fragmented specimen with the characteristic extreme lateral compression of lentil (*Lens culinaris*) was present in a sample from Area H. All of the other specimens were more or less spherical in shape, with

most lacking their testa. Several specimens of pea were identified on the basis of shape, size (>5mm) and the presence of a large hilum cavity. Two specimens retained a fragment of rough seed coat and another a clearly smooth fragment suggesting that both wild and domestic forms were present. Many other spherical legume seeds were present of greater than 2mm in diameter but lacked their testa making identification very difficult beyond sub-family Vicieae. One specimen again had a small fragment of rough coat and another a relatively large oval-shaped hilum, but species was impossible to identify further. The large-seeded legumes had a very strong correlation with cereal remains and also many possible weed species (Table S5).

Weeds of cultivation

Given the lack of *in-situ* crop stores it is difficult to identify a weed flora with certainty, however, among the wild plant seeds were a 1694 probable crop weed seeds (4.7% of the total assemblage) whose ecology and association with crops elsewhere (7, 5, 11) suggest that Boncuklu saw cropping and crop processing. Among these, obligate crop weeds *Adonis* and *Lithospermum officionalis* were present, as were *Eremopyrum*, large-seeded *Galium*, *Rumex*, *Descurania* and *Stipa* species, all identified as probable weeds from Çatalhöyük East (12). A number of others, including *Alyssum*, *Lepidium*, *Heliotropium*, *Silene*, *Trifolium* and a range of other small-seeded legumes have been identified as probable weeds by Willcox et al as they increase in presence during the Neolithic (11-Table 12). An independent means of identifying weed species is to use statistical correlation as shown in Table S6, which shows the wild taxa with strong, significant Pearson's (Linear R) correlation values to both the cereal remains (chaff and grains) and the large-seeded legumes, suggesting that they entered and were deposited in the site together. Many of the possible weed seeds described above have strong correlation values, as do taxa such as the knotweeds (*Polygonum* species). Interestingly, the most abundant seed types including *Bolboschoenus*, *Atriplex* and *Phalaris* had very high correlation values with the crop plants, as did several of the wetland plant taxa such as water plantain (*Alisma*) and pondweed (*Potamogeton*). The data supports the notion that Boncuklu had a developed weed flora and that it included plants of wet/heavy soils, suggesting cultivation on wetland margins near the site, as well as drier areas as indicated by plants such as *Taeniatherum*. The fact that weed seeds correlated well with both legumes and cereals suggests they probably derived from cultivation of both, though the data also could be read is indicating cereals were weeds of legumes or vice-versa.

Gathered plant foods

Several obvious gathered plant foods were present including nutshell of both orientalis (*Amygdalus orientalis/graeca*) and communis (*Amygdalus communis* type) almonds, terebinth nutlets (*Pistacia* sp.) and the stones of hackberry (*Celtis tournefortii*/*glabrata*). These gathered nuts and fruits, high in oil and protein, were common but nowhere preserved in large volume, though were present in >59% of the site samples. Not present in Table S4 are the tubers and rhizomes of clubrush (*Bolboschoenus glaucus*), present in 77.8% of samples, often in large quantities (Fig. S6), among unidentified fragments of tubers/rhizomes possibly from the same species. These are thought to have been collected as food from the wetland surrounding the site. Numerous wild seeds, especially those of wetland plants including numerous aquatics, were present at the site, dominating the archaeobotanical assemblages. Many of these seeds are well known in seed assemblages from Epipalaeolithic and Aceramic Neolithic assemblages in the Fertile Crescent and have been identified as foods (13). This is possible at Boncuklu, though they also may have derived from reed/plant used as

fuel – see also above. They may also have been derived from crop weeds (Table S5), though given the low incidence of crops this seems to be unlikely as the sole source. Given this complex taphonomy plus the lack of storage at the site, it is difficult to confirm the exploitation of this food source, even though it may have contributed to the heightened stable isotope N values in human skeletons (SI Text 6).

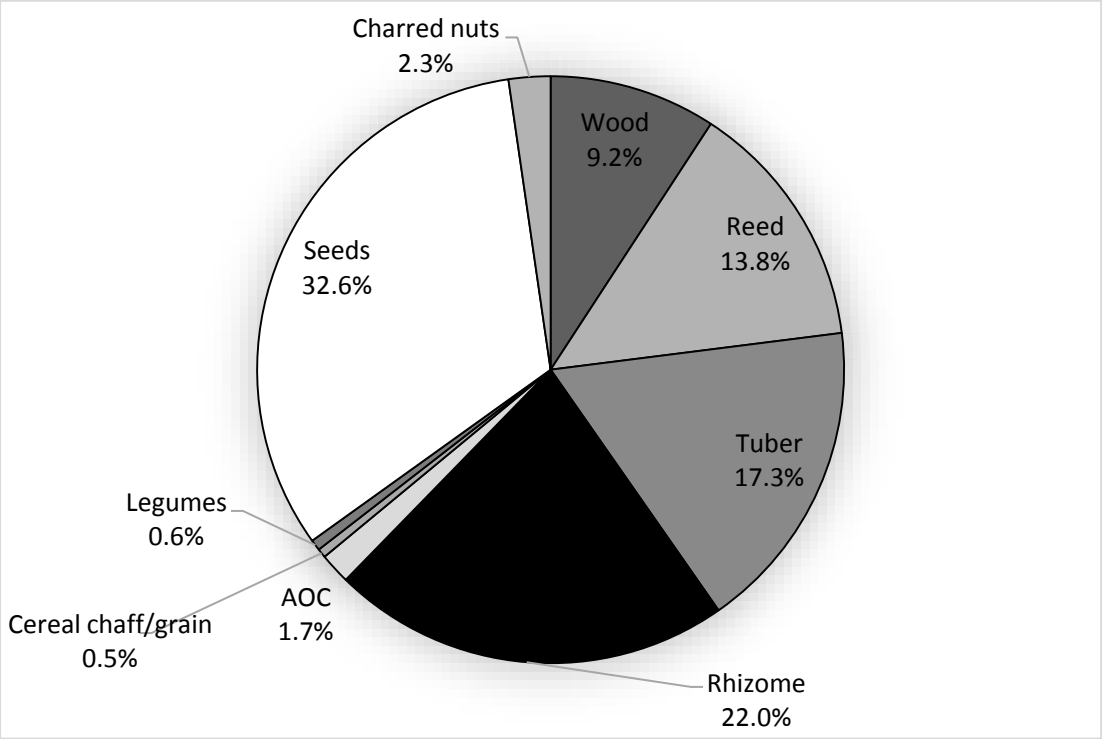

Figure S6 Composition of samples at Boncuklu by weight (n = 45)

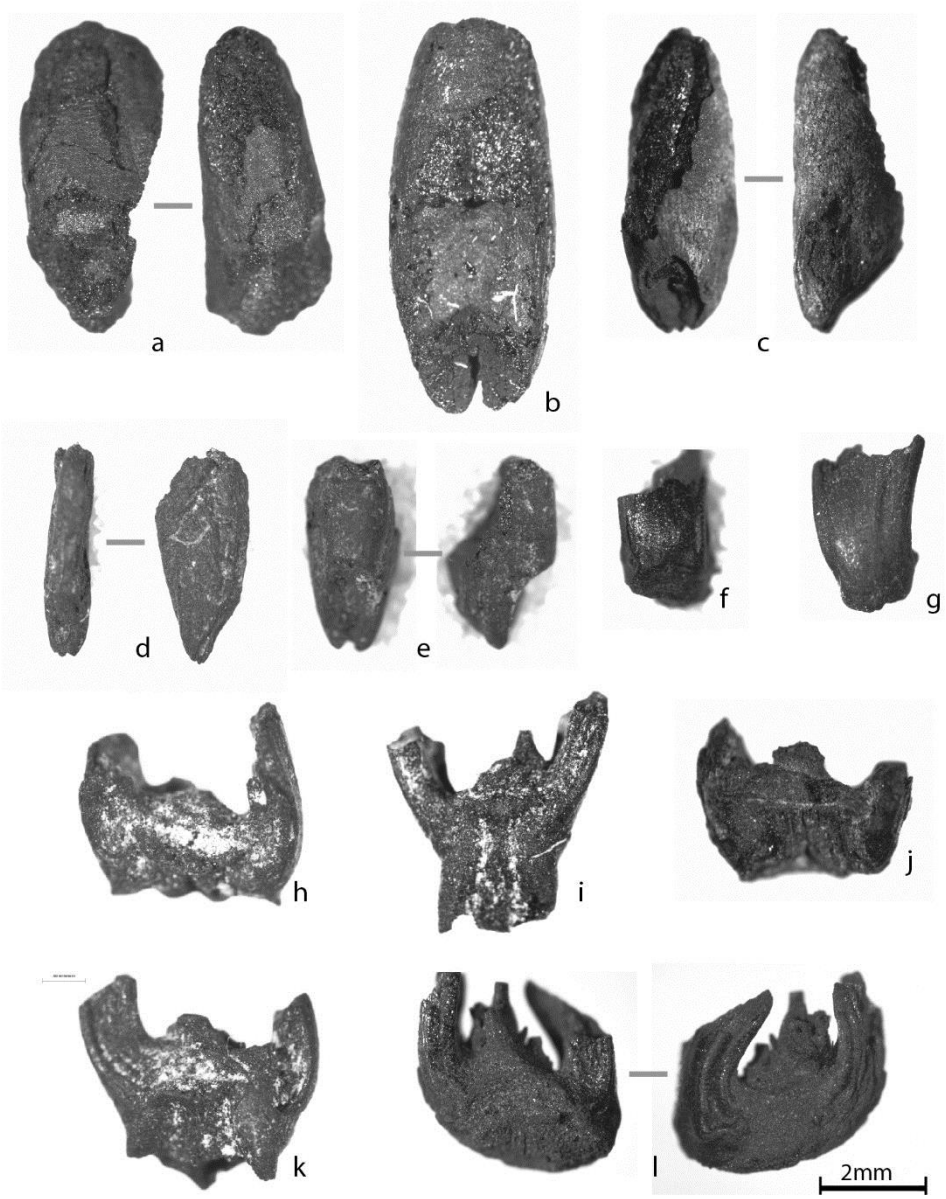

Figure S7 Plant macrofossil remains from Boncuklu: a. dorsal and lateral view of damaged smaller type emmer grain, probably from wild emmer; b. larger 'cultivated' type emmer grain; c. damaged probable emmer grain; d. narrow fragment of wild 1-grained einkorn; d. wide-type 1-grained einkorn; f. einkorn glume in lateral view showing narrow base and strong primary/secondary keels g. emmer glume in lateral view, showing wide base, weak secondary keel and tertiary vein; h. emmer spikelet fork with domestic type rachis scar; i. emmer spikelet fork with domestic type rachis scar; j. emmer spikelet fork with damaged rachis but lacking the projection above the glume insertion of domestic types; k. 'new type' glume wheat sub-basal spikelet fork with domestic type rachis scar; l. abaxial and adaxial view of 'new type' glume wheat spikelet fork with strong primary and secondary keels, high glume insertion parallel to wide, rachis scar.

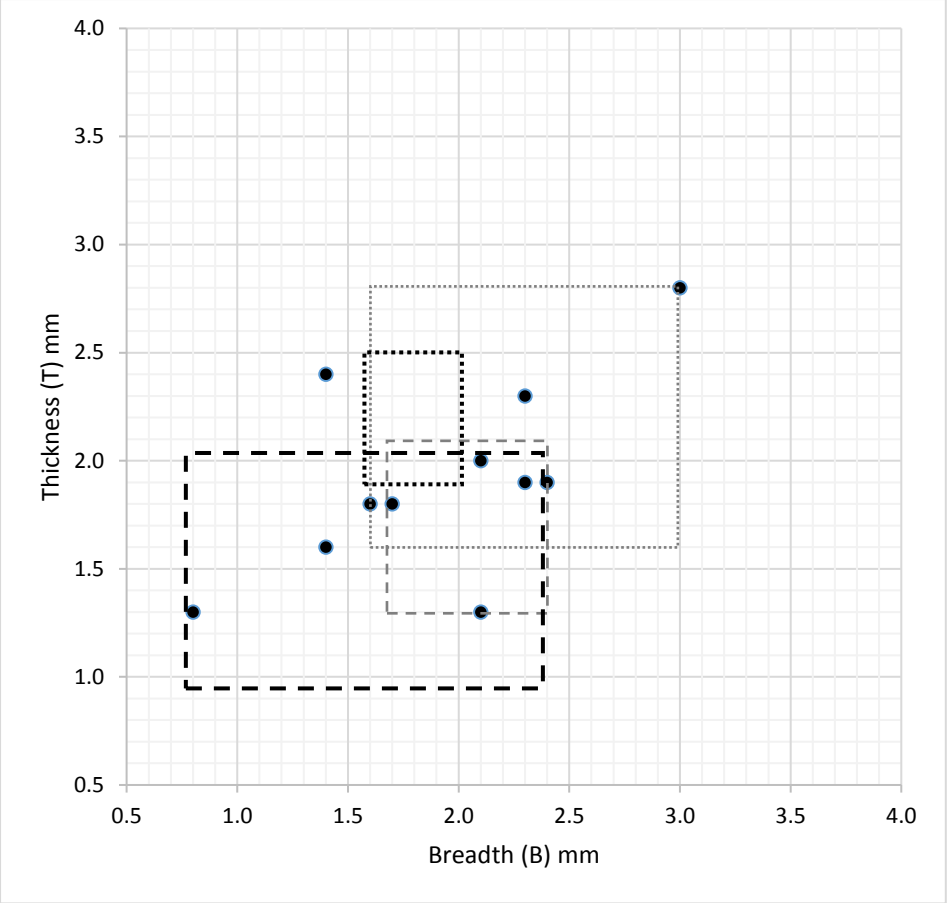

Figure S8. Breadth and thickness measurements for grains from Boncuklu (•) plotted against maximum and minimum measurements for grains from published sources (A = wild einkorn; B = cultivated/domestic einkorn; C = wild emmer; D cultivated/domestic emmer).

Number of contexts = 45	Volume of processed soil = 3184 litres	Density of plant remains (g/l) = 0.02			
	NISP	**SUM**	**%**	**Ubiquity**	**%Frequency**
	Total	36060	100		
	Cereal grain	38	0.11	11	24.4
	Cereal chaff	31	0.09	12	26.7
	Cereal grain and chaff	69	0.20	19	42.2
	Pulses	307	0.85	22	48.9
	Nutshell (charred)	257	0.71	25	55.6
	Nutshell (not charred)	346	0.96	32	71.1
	Wild seeds charred	29390	81.50	45	100
	Wild seeds not charred	5691	15.78	45	100
	Tubers/Rhizome	-	-	35	77.8
	Taxon	**Component**	**Sum**	**Ubiquity**	**%Frequency**
Cereals	*Triticum boeoticum/T. monococcum*	1 grained, grain MNI	9	5	11.1
	Triticum boeoticum/T. monococcum	2 grained, grain MNI	1	1	2.2
	T. dicoccoides/T. dicoccum	Large grain MNI	2	2	4.4
	T. dicoccoides/T. dicoccum	Small grain MNI	4	2	4.4
	Triticum indeterminate	Grain MNI	3	3	6.6
	Cereal indeterminate	Grain MNI	6	6	13.2
	Triticum boeoticum/T. monococcum	Spikelet fork, indet. rachis scar	2	2	4.4
	Triticum boeoticum/T. monococcum	Glume base	3	3	6.6
	T. dicoccoides/T. dicoccum	Spikelet fork, domestic rachis scar	2	1	2.2
	T. dicoccoides/T. dicoccum	Spikelet fork, indet. rachis scar	3	2	4.4
	T. dicoccoides/T. dicoccum	Glume base	5	5	11.1
	Triticum "New type"	Spikelet fork (sub-basal), domestic rachis scar	1	1	2.2
	Triticum "New type"	Spikelet fork, indet. rachis scar	1	1	2.2
	Triticum indeterminate	Spikelet fork, indet. rachis scar	3	3	6.6
	Triticum indeterminate	Glume base	5	4	8.9
Legumes	*Pisum* sp.	Seed MNI	8	2	4.4
	Lens culinaris	Seed MNI	1	1	2.2
	Viceae spp. large-seeded	Seed MNI	72	21	46.7
Fruits/nuts	*Amygdalus orientalis/graeca*	Nutshell NISP	87	14	31.1
	Amygdalus communis type	Nutshell NISP	2	2	4.4
	Pistacia sp.	Nutshell NISP	72	18	40.0
	Indeterminate	Nutshell NISP	96	11	24.4
	Celtis tournefortii/glabrata	Nutshell NISP	346	34	75.6
	Amygdalus orientalis/graeca	Nutshell MNI	16	14	31.1
	Amygdalus communis type	Nutshell MNI	2	2	4.4
	Pistacia sp.	Nutshell MNI	24	18	40.0
	Celtis tournefortii/glabrata	Nutshell MNI	224	34	75.6
Other seeds	*Phalaris arundinacea*	Seed MNI	14970	42	93.3
	Bolboschoenus glaucus	Seed MNI	4599	41	91.1
	Atriplex sp. and *Chenopodium* sp.	Seed MNI	4209	38	84.4
	Eleocharis sp.	Seed (siliceous) MNI	3070	35	77.8
	Buglossoides arvensis	Seed MNI	2434	34	75.6
	Puccinellia sp.	Seed MNI	1689	27	60.0
	Helianthemum sp.	Seed MNI	631	22	48.9
	Brassicaceae spp.	Seed MNI	556	20	44.4
	Scirpoides holoschoenus	Seed MNI	421	17	37.8
	Silene sp.	Seed MNI	320	15	33.3
	Rumex sp.	Seed MNI	269	15	33.3
	Gramineae small forms (<4mm)	Seed MNI	230	24	53.3
	Leguminosae Small seeded	Seed MNI	182	14	31.1
	Lamiaceae	Seed MNI	120	14	31.1
	Galium sp. (small-seeded)	Seed MNI	80	17	37.8
	Polygonum persicaria type	Seed MNI	74	12	26.7
	Polygonum aviculare type	Seed MNI	72	14	31.1
	Schoenoplectus lacustris	Seed MNI	68	10	22.2
	Polygonaceae	Embryo MNI	52	11	24.4

Alismataceae	Seed MNI	52	12	26.7
Bromus sp.	Seed MNI	33	17	37.8
Taeniatherum caput-medusae	Seed MNI	27	12	26.7
58 other seed types <20% Ubiquity	Seed MNI	961		

Table S4 Summary archaeobotanical data from Boncuklu. NISP = number of identified specimens; MNI = Minimum Number of Individuals. For terminology regarding rachis scars see refs. 2 and 12.

Charred seeds	**P**	**Cc**	**Sc**	**Cg**	**Sg**	**Cl**	**Sl**
Cereal chaff	-	-	-	**0.669**	<0.001	**0.851**	<0.001
Cereal grain	-	**0.669**	<0.001	-	-	**0.853**	<0.001
Adonis sp.	A	0.456	0.002	0.069	0.650	0.220	0.142
Alisma sp.	A	**0.602**	<0.001	0.378	0.01	0.490	<0.001
Bromus sp.	A	**0.57**	<0.001	0.457	0.001	**0.648**	<0.001
Taeniatherum caput-medusae (seed)	A	**0.633**	<0.001	**0.780**	<0.001	**0.817**	<0.001
Indeterminate A	A	0.400	0.006	**0.521**	<0.001	0.465	0.001
Polygonum aviculare type	A/B	0.148	0.321	**0.534**	<0.001	**0.840**	<0.001
Polygonum persicaria type	A/B	**0.666**	<0.001	**0.555**	<0.001	0.244	0.098
Astragalus/Trigonella types	B	**0.518**	<0.001	0.05	0.743	0.265	0.075
Atriplex spp.	B	**0.736**	<0.001	**0.725**	<0.001	**0.780**	<0.001
Lamiaceae	B	0.449	0.002	0.477	0.001	0.484	<0.001
Galium sp. (small-seeded forms)	B	**0.519**	<0.001	**0.619**	<0.001	**0.590**	<0.001
Phalaris arundinacea	B	**0.769**	<0.001	**0.761**	<0.001	**0.781**	<0.001
Potamogeton sp.	B	**0.512**	<0.001	0.450	0.002	0.446	<0.001
Rumex sp.	B	**0.726**	<0.001	**0.675**	<0.001	**0.833**	<0.001
Silene sp.	B	**0.581**	<0.001	**0.587**	<0.001	**0.574**	<0.001
Alyssum sp.	B/C	**0.555**	<0.001	0.163	0.28	0.305	0.039
Bolboschoenus glaucus	B/C	**0.773**	<0.001	**0.781**	<0.001	**0.821**	<0.001
Siliceous/mineralised seeds	**SP**	**CC**	**SC**	**CG**	**SG**	**CL**	**SL**
Lithospermum arvense type	A	**0.713**	<0.001	**0.61**	<0.001	**0.679**	<0.001
Lithospermum officionale	A	0.331	0.024	0.448	0.002	0.455	0.001
Scirpioides holoschoenus	B	0.423	0.003	0.383	0.009	0.417	0.004

Table S5 Pearson correlation data for taxa with significant correlation values to cereal chaff (c), grains (g) and large-seeded legumes (l) present in >10% of samples. P = seed size property (A = same or larger than grain; B = smaller than grain; C = stays in seed head (follows Stevens 1996); C = correlation value; S = Significance (e.g. Cg = Correlation to grain; Sg = significance of correlation to grain). Entries in grey have low correlation and significance values; correlation values in bold >0.500.

SI Text 3: Phytolith analysis

Emma Jenkins, Ambroise Baker, Sarah Elliott

Phytolith assemblages are subject to different taphonomic factors compared to charred macrofossils and thus used in combination with these overcome questions of the representativeness of the archaeobotanical record for environmental conditions and the presence of food plants. Both Boncuklu and Pınarbaşı are characterised by a high density of phytoliths, between 11 and 21% by weight at Pınarbaşı (1 - Table 4 and Fig. 5), with higher weights per gram in some samples at Boncuklu and a mean of 26.5% (Fig. S9). Clearly much of the sites' sediment consisted of decayed vegetative plant material. Both assemblages show the presence of high proportions of reed phytoliths, at Boncuklu mean 65.3%, and some sedges. This strongly indicates the presence of marsh, lake or riverine habitats reasonably close to both sites and their regular exploitation.

A contrast between the sites lies in the presence of the phytoliths of wheat (33% presence) and barley (57% presence) in the Boncuklu assemblages (Fig. S9), taxa completely absent from 10^{th}-9^{th} millennium Pınarbaşı (1). While wheat is probably from crop species that dominate the modest cereal macrofossil assemblages, barley phytoliths may be from wall barley (*Hordeum murinum*) and related weedy types, documented in the macrobotanical seed assemblage, as cultivated barley is not demonstrably present in the 9^{th}-8^{th} millennium seed assemblage (SI Text 2). Wheat occurs in only one third of the samples and with very low frequency in most of those, corresponding well with Boncuklu's macrofossil record, as does the presence of husk phytoliths with macrofossil evidence suggestive of on-site crop (SI Text 2).

The high proportion (83.8%) of monocot phytoliths found in a conjoined state indicates that the plants in which these phytoliths formed received sufficient water for their requirements during cultivation (14, 15), including the cereals, consistent with growth in a well-watered environment. It also suggests that these conjoined phytoliths remained relatively undisturbed by taphonomic processes because we know that they can be subject to mechanical breakage (16).

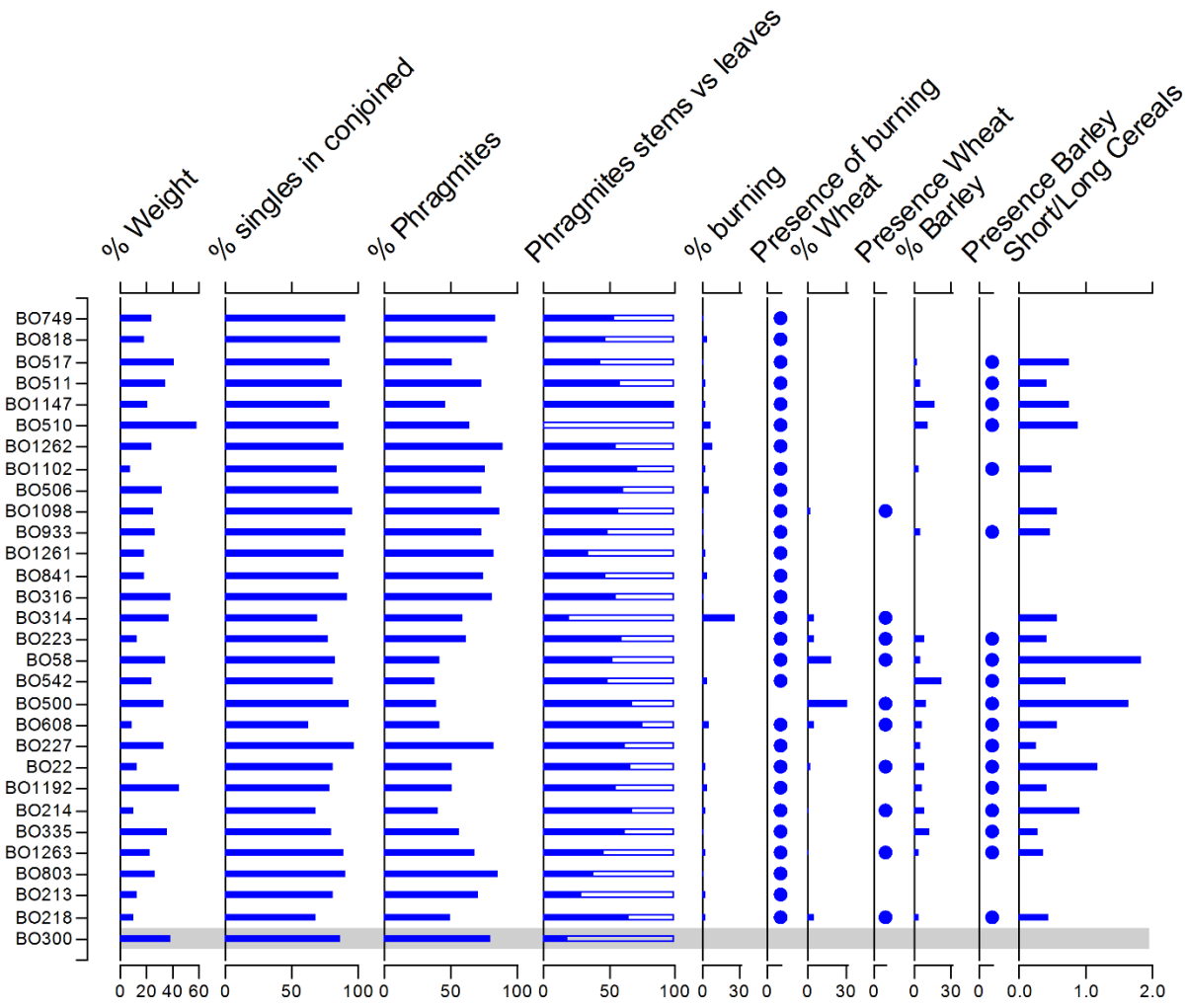

Figure S9. Phytolith evidence from Boncuklu by context

SI Text 4: Mammal remains from Boncuklu and Pınarbaşı
Louise Martin and Caroline Middleton

Wild aurochs *(Bos primigenius)* was a key species exploited at both Pınarbaşı, where it has the highest NISP, and Boncuklu, where it is the second most abundant taxon (Table 4). Morphometric analysis of postcranial elements, plus the morphology of horn-cores, demonstrate that *Bos* remains belonged to morphologically wild animals. Given the meat-weights of these large animals they would have provided the most meat to the inhabitants of both sites.

In terms of other large mammal species, however, there is a notable contrast is between the sites. At Pınarbaşı caprines are next most common, with sheep outnumbering goats. At Boncuklu, S*us* is the highest represented taxon at 48% (Table 4). To some extent this reflects local environments: Pınarbaşı is adjacent to hills, while Boncuklu sits in wetlands 15-20kms distant from uplands, the caprines favoured habitat. However, Pınarbaşı was likely next to lake and marsh areas (in the Hotamış basin, until recently a permanent water body), and therefore the significantly lower representation of *Sus* at Pınarbaşı is unexpected. There is also a notably low percentage of caprines in the Boncuklu assemblage, compared to Pınarbaşı. The region lies within the distribution of both wild sheep (*Ovis orientalis*) and goats (*Capra aegagrus*), and to date the small numbers of metrical skeletal elements has hindered morphological analysis of the wild or domestic status of caprines at either site. The results of stable Carbon and Nitrogen isotope analyses, however, provide further insights on this question (SI Text 4), as does the presence of herbivore dung detected as spherulites (17).

Equids (probably the half-ass *Equus hemionus*, but could also include wild horse, *Equus caballus ferus*) seem hunted in similar measure at both sites, probably on the steppe grasslands at some distance from the settlements. Deer are also present at both sites, indicating exploitation of the wooded hill areas and woodland fringes. Pınarbaşı sees a surprisingly low representation of deer given the site's location close to hills and woodland - as indicated by anthracological evidence. The relatively high count of fox elements at the site may reflect skin/fur procurement, which is being explored further through skeletal-part representation.

SI Text 5: Caprine stable isotopes and the question of caprine management
Caroline Middleton

Carbon and nitrogen stable isotopes ($\delta^{13}C$ and $\delta^{15}N$ values of bone collagen) are indicators of diet, reflecting the C and N isotopes of the plants (herbivores) and animals (omnivores and carnivores) consumed by the source animal. The research reported here, based on a PhD thesis at University of Liverpool, investigated the possibility of human intervention in animal behaviour as evidenced via changes in carbon and nitrogen isotopes, including diet, but also other factors that can influence $\delta^{13}C$ and $\delta^{15}N$ values such as water availability and stress. It was hypothesized that the human management of species preceding morphological domestication, such as herding or related forms of control, might have affected animal diets and physiology through one or more of the following phenomena: removal from their natural habitats and thus modifying natural grazing and browsing opportunities, access to pasture, penning and restricted mobility, access to sufficient water and foddering.

Carbon isotope values relate partly to the varied photosynthetic pathways of particular plants. Both C_3 and C_4 plants were present in the Late Glacial and early Holocene on the Konya plain, with the C_4 plants in the more arid and saline areas (1, 4, 5, 7). Whilst universal values for C_3 and C_4 plants exist, there are local variations. Çatalhöyük East values indicate that a consumer with an exclusively C_3 diet would have carbon isotope values of around -18‰, while an exclusively C_4 feeder would have carbon isotope values of around -7‰ (18). Nitrogen isotopes reflect both the amount of dietary protein in a diet and position within the foodweb, for example, distinguishing herbivore from carnivore, and marine plants from terrestrial ones. The relationship between the $\delta^{15}N$ values of soil and plants, and factors such as aridity, salinity, fire and grazing is complex, involving an intricate interplay between the quantity of N flowing through the ecosystem, its source, utilization and fractionation (19).

Isotopic research identified dietary signatures indicative of morphologically domestic caprines from Çatalhöyük East and West (Fig. S10): Carbon and Nitrogen isotope values from Epipalaeolithic Pınarbaşı (Fig. S10) established a dietary signature for caprines that were extremely unlikely to have been affected by human management ('Unaffected Signature' on Fig. S10). These two signatures allowed the examination of changes in $\delta^{13}C$ and $\delta^{15}N$ values through time, and thus, of the diet and conditions of early caprines living on the Konya Plain preceding and leading up to the morphologically domestic caprines of Çatalhöyük East.

Fig S8 shows the distinct differences in $\delta^{13}C$ and $\delta^{15}N$ values between the domestic caprines of Çatalhöyük East and Çatalhöyük West (c. 7100–5500 cal BC) and the unaffected signature from Pınarbaşı. The morphologically domestic Çatalhöyük caprines have, almost without exception, higher $\delta^{15}N$ values, with a significant proportion of animals consuming C_4 plants. This signature reflects the diet of domestic animals affected by human control; probably consuming plants from more arid steppe pastures or more saline marsh areas of the plain; this would have contrasted with the diet of the caprines living in their natural habitat — the moister and more wooded hills, as well as the plain edge setting surrounding the Konya Plain. The two signatures are quite distinct.

Six caprine specimens from Boncuklu have been analysed and, it seems that most have dietary signatures unaffected by human control/intervention (Fig. S11) with $\delta^{13}C$ and $\delta^{15}N$ values similar to the Pınarbaşı animals. However, two of the Boncuklu caprines show diets more akin to Çatalhöyük caprines: most notably the elevated $\delta^{15}N$ values.

The high $\delta^{15}N$ values in some Boncuklu caprines, comparable to the levels seen in the Çatalhöyük animals, could reflect differences in diet and plants consumed. Salinity, aridity and manuring can all increase plant nitrogen levels, increases that would then be passed onto the consumer. Plants showing such effects are likely to be found in the more arid plain/saline marsh areas rather than surrounding hills and their fringes, i.e. in areas that would not have been the natural caprine habitats of the region. It is also possible that increased $\delta^{15}N$ values are the result of direct action by humans: this could include some form of stress, perhaps due to reduced access to water, impoverished conditions, lack of food, or restricted penning, as, in the case of the latter, evidenced at contemporary Aşıklı Höyük (20). It is difficult, at present, to identify the exact reason for the raised $\delta^{15}N$ values, though it is likely to be a combination of factors. Whatever the reason, be it plants grazed in ecological settings different to the local natural habitats, the direct impact of human control, or indeed a combination of such factors, it seems likely that some caprines killed at Boncuklu had been taken out of their natural habitats in the hills and were grazing on the plain and/or were foddered, and/or suffered consequent stress and more restricted access to water: all of which are likely to indicate direct human control and therefore herding activity.

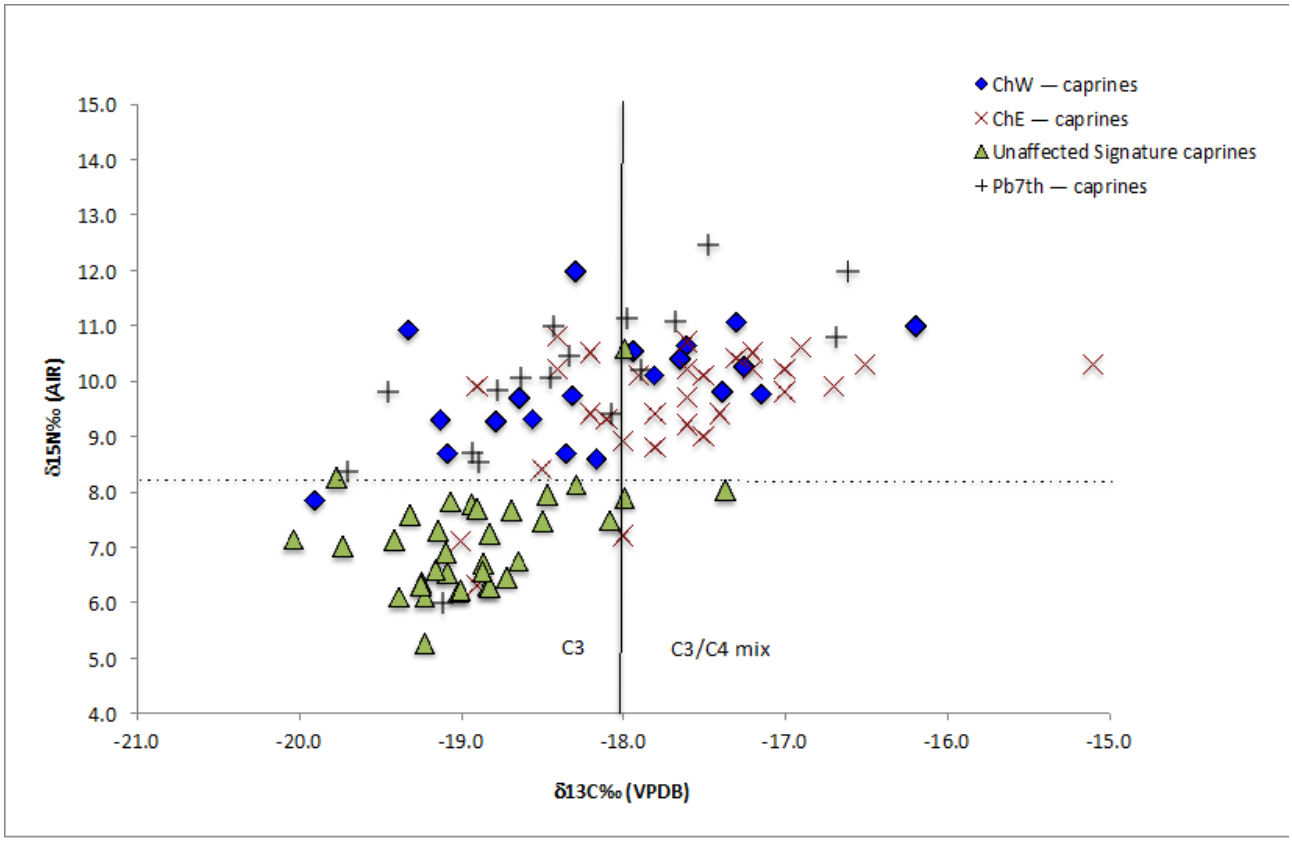

Fig. S10. Caprines from Çatalhöyük West (ChW), Çatalhöyük East (ChE) and Pınarbaşı 7th millennium (Pb) plotted against the unaffected signature for caprines (Epipalaeolithic Pınarbaşı and 9th millennium Pınarbaşı).

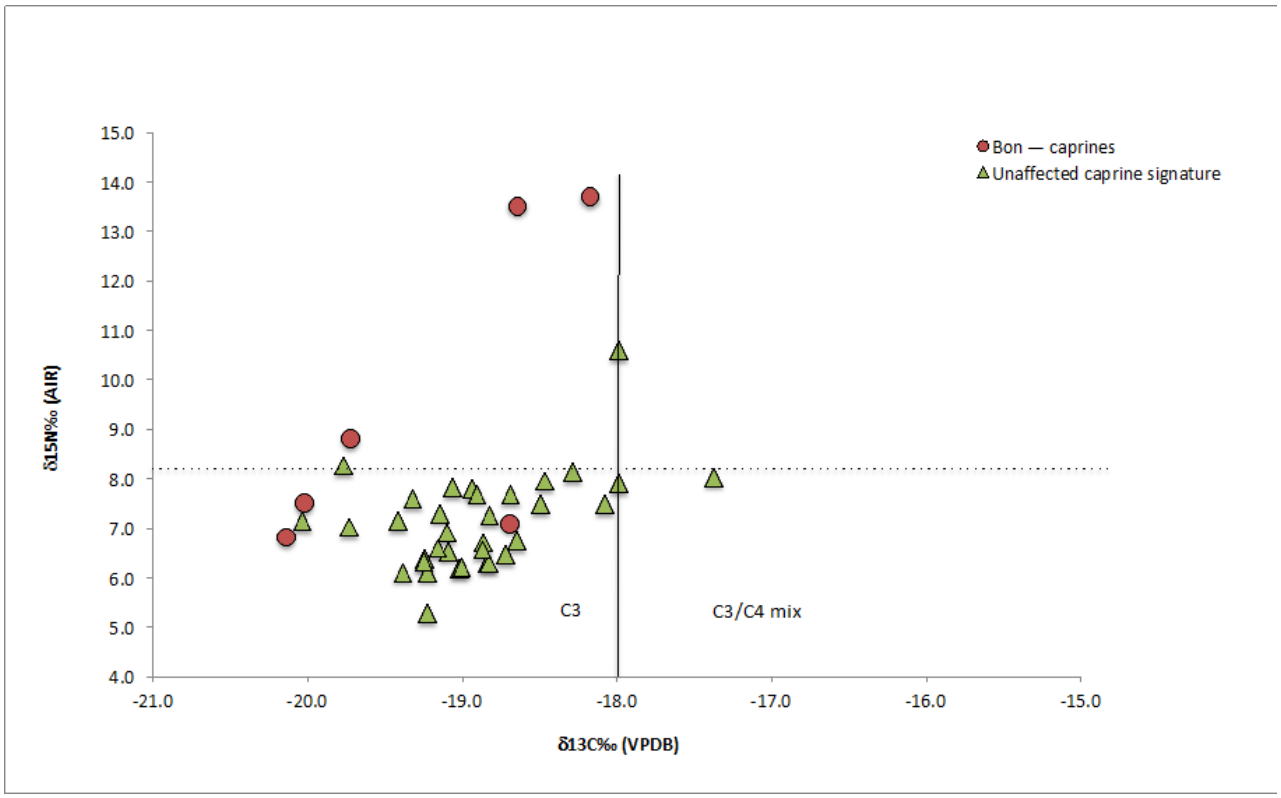

Fig. S11. Caprines from Boncuklu (Bon) plotted against the unaffected signature (Epipalaeolithic Pınarbaşı and 9th millennium Pınarbaşı).

SI Text 6: Human stable isotope analysis
Dr Jessica Pearson

Table 3 shows nitrogen stable isotope mean values of human bone samples from Pınarbaşı (for Epipalaeolithic data see ref. 4), Boncuklu and Çatalhöyük (for the latter see ref. 21) compared to a number of the principal (determined by NISP – see SI Text 4) and biggest meat-weight contributor species at those sites. At Epipalaeolithic Pınarbaşı caprines and *Bos* sp. (aurochs) would have provided approximately similar amounts of meat amongst the main mammals contributing to the human diet, though caprines might have supplied slightly more if the large and medium mammal bone is assigned to aurochs and caprines respectively (4). Therefore, with a mean diet spacing of around Δ^{15}N 6.5 ‰ (an average of the spacing for caprines and *Bos* sp.) there is a strong suggestion that high trophic level animal protein was important in the diet of Epipalaeolithic humans at Pınarbaşı, likely including a role for fish and wetland birds (4). When compared to the diet consumer spacings at the later sites it also suggests a reduction in animal protein in the diet between Late Glacial and early Holocene humans on the Konya Plain, which is commensurate with an increasing role played by plants in human diet in the early Holocene.

At Boncuklu, based on NISP, the predominant meat consumed would have been aurochs and boar, but the larger body size of aurochs would have provided c. 6 times more meat than boar so a Δ^{15}N diet spacing between humans and these mammals would be a little over 3 ‰. Taking into account the contribution of fish, a frequent food source at Boncuklu, and given a human:fish (n=6) diet spacing of Δ^{15}N 3.2 ‰, this would not significantly alter this picture. This represents a spacing not significantly different to that at Çatalhöyük, a site dominated by caprines (c. 70% NISP) and *Bos* sp. (c.19% NISP) with an overall mean spacing of c. Δ^{15}N 3‰. Therefore, it seems likely that the inhabitants of Boncuklu Höyük had relative contributions of animal to plant protein at a broadly similar level to those living at Çatalhöyük. However, the evidence of plant remains at these two sites suggests significant contrasts in the contribution of different plants to the diet.

At $10^{th}/9^{th}$ millennium Pınarbaşı caprines are a more important element of the fauna than at Boncuklu (Table 4), however, *Bos* sp., likely all aurochs, is the predominant element of the faunal assemblage and would have been by far the biggest meat provider, providing c. 25 times as much meat as the caprines. Thus, the Δ^{15}N diet spacing in relation to those species, weighted for meat contribution at Pınarbaşı is likely to be close to 2‰, and it seems very likely that lower amounts of animal protein are represented in the Pınarbaşı human diet than at Çatalhöyük and Boncuklu. This is interesting given the dearth of evidence for significant consumption of cereals or legumes at $10^{th}/9^{th}$ millennium cal BC Pınarbaşı. Whilst aquatic resources, birds and fish made a contribution to the Pınarbaşı human diet, this contribution seems somewhat less than at Boncuklu, judging by the frequency of fish and bird bones at the two sites. Such an aquatic contribution is unlikely to explain either the full extent of the difference between Boncuklu and $10^{th}/9^{th}$ millennium Pınarbaşı or Çatalhöyük and $10^{th}/9^{th}$ millennium Pınarbaşı diet spacings discussed above. These factors suggest that the relatively high in protein nut remains at early Holocene Pınarbaşı represent an important contribution to the diet, probably a more important protein contribution than that made by the cereals and legumes to the diet of the inhabitants of Boncuklu.

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